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DRAFT

Summary of

Research

2009

Submitted by the Faculty
Compiled by the
Office of the Associate Provost and Dean of Research
Naval Postgraduate School
Monterey, CA 93943-5138

NAVAL POSTGRADUATE SCHOOL
Monterey, California

DANIEL T. OLIVER
President

LEONARD A. FERRARI
Provost

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13. ABSTRACT (Maximum 200 words.) This report contains project summaries of the research undertaken at the Naval Postgraduate School. A list of recent publications is also included, which consists of conference presentations, books, contributions to books, published journal papers, and technical reports. The research was conducted in the areas of National Security Affairs, Computer Science, Defense Analysis, Information Science, Operations Research, Aeronautics and Astronautics, Electrical and Computer Engineering, Mathematics, Mechanical Engineering, Meteorology, Oceanography, Physics and Business and Public Policy. This also includes research by the Space Systems Academic Group, the Cebrowski Institute (formerly the Institute for Information Innovation and Superiority, I2SI), the Wayne E. Meyer Institute of Systems Engineering (formerly the Institute for Defense Systems Engineering and Analysis, IDSEA), the MOVES Institute (Modeling, Virtual Environments, and Simulation), and the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS).				
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THE NAVAL POSTGRADUATE SCHOOL MISSION

Enhance the combat effectiveness of the Navy and Marine Corps by conducting and directing advanced education of commissioned officers, and providing such other technical and professional instruction as may be prescribed to meet the needs of the Naval service. In support of the foregoing, and to sustain academic excellence, foster and encourage a program of relevant and meritorious research.



PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four Graduate Schools, Research and Education Institutes, Research Centers, and the School of Aviation Safety. This volume contains research summaries for the projects undertaken by faculty during 2007. The summaries are grouped by School and Institute and include an overview, faculty listing, and a compilation of publications/presentations.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department/Group Chair, or the Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.edu (e-mail). Additional information is also available at the *RESEARCH AT NPS* website, <http://www.nps.edu/Research/index.html>.

Additional published information on the Naval Postgraduate School Research Program can be found in:

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<http://www.nps.edu/Research/MoreThesisAbst.html>

Naval Postgraduate School Research Newsletter: A monthly newsletter highlighting Naval Post-Naval Postgraduate School faculty and student research:

<http://www.nps.edu/Research/Newsletters.html>

<p>This publication and those mentioned above can be found online at: http://www.nps.edu/Research/Publications/SummaryRes.html</p>

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military-relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/Department of Defense (DoD). It keeps our faculty current on Navy/DoD issues, and maintains the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, the DoD, other government agencies, and the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.
- Naval Postgraduate School Institutionally Funded Research (NIFR) Program: The institutionally funded research program has several purposes: 1) to provide the initial support required for new faculty to establish a Navy/DoD-relevant research area, 2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, 3) to enhance productive research that is reimbursably sponsored, and 4) to cost-share the support of a strong post-doctoral program.

The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2009 is provided in Figure 1.

INTRODUCTION

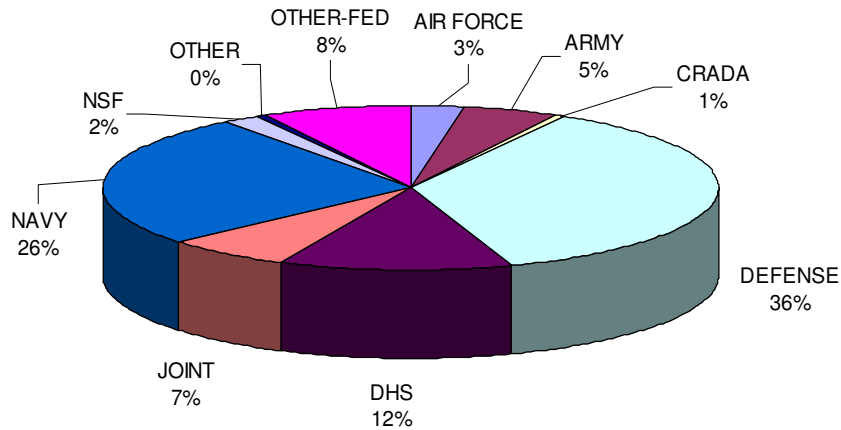


Figure 1. Profile of NPS Research and Sponsored Programs (\$152.6M)

The Chief of Naval Operations is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2009 is provided in Figure 2.

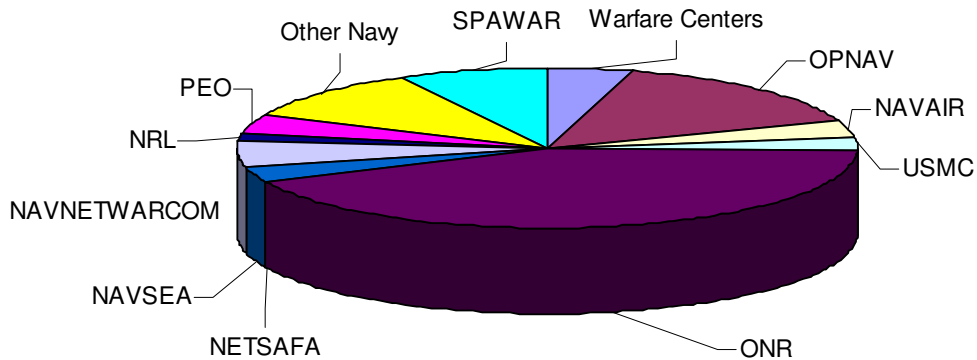


Figure 2. Profile of External Sponsorship (\$39.5M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

Daniel C. Boger
Dean of Research

December 2010

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**SCHOOL OF INTERNATIONAL
GRADUATE STUDIES**

**JAMES WIRTZ
DEAN**

**DEFENSE RESOURCES
MANAGEMENT INSTITUTE**

**CHARLES J. LACIVITA
EXECUTIVE DIRECTOR**

DEFENSE RESOURCES MANAGEMENT INSTITUTE

OVERVIEW:

Established in 1965, the Defense Resources Management Institute (DRMI) conducts professional education programs in resources management for senior military officers from all services and senior civilian officials from the United States and allied nations. The goal of the Institute's programs is to improve decision making skills related to the allocation and use of scarce resources in modern defense organizations. The DRMI programs are sponsored by the Office of the Secretary of Defense and use Naval Postgraduate School (NPS) faculty to teach its programs, which are conducted at NPS and other locations worldwide. Since 1965, over 14,000 U.S. and 17,000 international officials from 162 countries have participated in DRMI programs.

MISSION:

The DRMI research program is sponsored by the Office of the Secretary of Defense and is designed to support the multidisciplinary nature of the curriculum. The program exceeded \$378K in 2009.

RESIDENT COURSES OFFERED:

- Defense-Resources Management
- International Defense-Resources Management
- Senior International Defense-Resources Management
- Multiple-Criteria Decision Making
- Budget Preparation, Execution, and Accountability
- Streamlining Government through Outsourcing, Privatization, and Public-Private Partnerships
- Risk Management

FACULTY EXPERTISE:

DRMI's multidisciplinary faculty is drawn from the fields of management, economics, operations research, and systems engineering. The faculty is composed of both civilians and U.S. military officers representing all services.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. The School of International Graduate Studies' program exceeded \$23.6M in 2009.

DEFENSE RESOURCES MANAGEMENT INSTITUTE

Charles J. LaCivita
Professor and Executive Director
831-656-2445
clacivita@nps.edu

James Airola
Assistant Professor
831-656-2457
jsairola@nps.edu

Peter Frederiksen
Professor
831-656-2661
pcfeder@nps.edu

Allan C. Polley
Lecturer
831-656-2017
acpolley@nps.edu

Jomana Amara
Assistant Professor
831-656-3591
jhamara@nps.edu

Ronald Hughes, CDR, USN
Lecturer
831-656-2569
rshughes@nps.edu

Eva Regnier
Assistant Professor
831-656-2912
eregnier@nps.edu

Diana Angelis
Associate Professor
831-656-2051
diangeli@nps.edu

Stephen Hurst
Senior Lecturer
831-656-3480
sfhurst@nps.edu

Anke Richter
Associate Professor
831-656-2468
arichter@nps.edu

Kathleen Bailey
Research Associate
831-656-3013
ksbailey@nps.edu

Robert M. McNab
Associate Professor
831-656-3132
rmmcnab@nps.edu

Larry E. Vaughan
Senior Lecturer
831-656-2791
lvaughan@nps.edu

James S. Blandin
Professor
831-656-2318
jblandin@nps.edu

Francois Melese
Associate Professor
831-656-2009
fmelese@nps.edu

Kent D. Wall
Professor
831-656-2158
kdwall@nps.edu

Donald E. Bonsper
Senior Lecturer
831-656-2224
dbonsper@nps.edu

Luis Morales
Senior Lecturer
831-656-3669
lmorales@nps.edu

Natalie J. Webb
Associate Professor
831-656-2013
njwebb@nps.edu

Phillip A. Costain
Senior Lecturer
831-656-2909
pacostai@nps.edu

James H. Morris
Professor
831-656-2992
jhmorris@nps.edu

John Enns
Senior Lecturer
831-656-2306
jhenns@nps.edu

Chris Page, LtCol, USMC
Lecturer
831-656-2376
clpage@nps.edu

DEFENSE RESOURCES MANAGEMENT INSTITUTE

THE ECONOMIC AND SECURITY IMPLICATIONS OF MILITARY STABILIZATION EFFORTS: THE IRAQ SURGE AS A CASE STUDY

Jomana Amara, Assistant Professor
Defense Resources Management Institute
Sponsor: Unfunded

SUMMARY: The United States used a combination of economic, political, and military means to effect change in Iraq. Most notably, the United States used a buildup of security forces, the “surge,” as an intervention to stabilize the nation. This article uses structural change tests to determine the effect of the intervention on security-, economic-, and political-defined metrics of success. There appears to be compelling evidence that several events may have had a direct influence on security variables with the surge being one of the events. However, it is unclear whether economic and political order was enhanced as a result of the surge. (Under review in *American Economic Review*.)

FISCAL DECENTRALIZATION: THE JORDAN EXPERIENCE

Jomana Amara, Assistant Professor
Defense Resources Management Institute
Sponsor: Fulbright Research Grant

OBJECTIVE: To determine the extent of fiscal decentralization in Jordan. The principal investigator (PI) will generate measures that reflect the extent of sub-national autonomy, discretion in expenditures, and taxation arrangements between the central government and all the sub-national authorities.

SUMMARY: Since 1989 Jordan has been committed to implementing decentralization. However, the extent of decentralization is unclear. There is no systematic framework of local governance followed by all local governments in Jordan. Decentralized units vary in the authority and responsibility delegated to them by the governmental hierarchy and the implemented decentralization appears to be weak. For example, the governors, the heads of districts and sub-districts, and their staff are all employees of the Ministry of Interior and the governors are appointed by the cabinet. The governorates do not have their own source of revenue. Health and education responsibilities at the local level are directed by branches of central ministries. These efforts appear to be primarily deconcentration, the weakest form of decentralization.

Local governments seem to have very limited service delivery and revenue raising capacity. However, the function of local governments has been evolving over the past decade due to the promulgation of laws designed to encourage decentralization. It is unclear what scope of decentralization exists now, but the sense is that Jordan may not be fully benefiting from efficient assignment of functions between the tiers of government.

The purpose of this study is to determine the extent of fiscal decentralization in Jordan. The PI will generate measures that reflect the extent of sub-national autonomy, discretion in expenditures, and taxation arrangements between the central government and all the sub-national authorities, such as taxes versus user charges, the object of taxation, the definition of the taxpaying unit and of the tax bases, the tax rate schedules (including deductions and exemptions), the annual coefficient of taxation for the purpose of balancing the budget tax collection, and the rules over tax disputes.

OTHER:

Amara, J., “Fiscal Decentralization: The Jordan Experience,” (working paper).

KEYWORDS: Jordan, Fiscal Decentralization, Deconcentration

DEFENSE RESOURCES MANAGEMENT INSTITUTE

TRAUMATIC BRAIN INJURY EVALUATION INSTRUMENTS AND PROCESSES FOR CLINICAL FOLLOW-UP

**Jomana Amara, Assistant Professor
Defense Resources Management Institute**

Sponsor: Health Services Research and Development, Veterans Health Administration

OBJECTIVE: The primary aim of this ongoing two year study is a description and analysis of how the TBI evaluation process relates to VA care patterns, accounting for the impact of co-occurring psychiatric conditions and other relevant factors.

SUMMARY: Veterans with severe traumatic brain injuries (TBI) related to open wounds or other injuries requiring battlefield medical attention are generally well-documented by the medical systems of the Department of Defense (DoD) and the VA. The severity of TBI is a smooth continuum, however, and mild or moderate TBI can be difficult to identify because the actual damage is not as apparent. First, the physical symptoms, such as headache, dizziness, or changes in sensory abilities (visual or auditory), may be mistaken by the veteran or a clinician for signs of other physical ailments. Other symptoms, such as irritability or insomnia, are similar to those associated with other conditions, such as post-traumatic stress disorder (PTSD).

Because mild TBI can have lasting effects if not identified and treated, the U.S. Congress wants to determine that the VA appropriately identifies veterans with the condition, as well as those with PTSD. A taskforce of experts from several disciplines developed a screening instrument and protocol for the screening that recognized that veterans who screen positive for risk of TBI could have other conditions instead of TBI and need further evaluation. The protocol for the additional evaluation includes a 22-item neurobehavioral-symptom inventory, a comprehensive history and physical examination, diagnostic testing, and referral pathways for persistent symptoms.

TECHNICAL REPORT:

Amara, J. and Hendricks, A., "Patterns and Costs of OEF/OIF Veteran Utilization of VA Services," (working paper).

KEYWORDS: TBI, PTSD, Health Care, VA

THE USE OF IMPROVISED EXPLOSIVE DEVICES AS A STRATEGIC WEAPON ON A SUBNATIONAL LEVEL IN IRAQ

**Jomana Amara, Assistant Professor
Defense Resources Management Institute**

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To investigate the dynamics of violence at the provincial level in Iraq. The research will focus on each of the 18 provinces in Iraq and further disaggregate the analysis by type of weapon system.

Current analysis was extended to each of the 18 provinces in Iraq and the analysis was further disaggregated by type of weapon system. It is believed that this approach is foundational to the stated intent of understanding the economic incentives underlying the formation and generation of improvised explosive device (IED) violence. If a province is unstable in terms of the adherence of violence to a power law distribution, then the province is less likely to be successful with respect to the transfer of authority to the host nation government, regardless of whether the province is in Iraq or Afghanistan. Thus, a tool is being developed by which researchers can explore, regardless of location but conditional on causality data, whether sub-national regions are stable enough for the application of non-lethal shaping tools or whether the provision of security through lethal means is paramount.

OTHER:

Amara, J. and McNab, R., "Use of IEDs as a Strategic Weapon on a Sub-National Level in Iraq," 2008 (working paper).

DEFENSE RESOURCES MANAGEMENT INSTITUTE

KEYWORDS: Iraq, Province, Violence, Power Law, Kolmogrov-Smirnov

ACQUISITION REVIEWS: COSTS AND INCENTIVES

Diana I. Angelis, Associate Professor

Francois Melese, Professor

Defense Resources Management Institute

Raymond Frank, Senior Lecturer, Graduate School of Business and Public Policy

John T. Dillard, Senior Lecturer

Graduate School of Business and Public Policy

Sponsor: Acquisition Research Program, Naval Postgraduate School

SUMMARY: Using the results of a survey of Air Force program managers, the principal investigators explored the cost and incentive differences between programmatic and technical reviews. This research examined the differing roles the program manager plays in each review from a principal-agent perspective.

CORRUPTION IN IRREGULAR WARFARE

Robert M. McNab, Associate Professor

Defense Resources Management Institute

Sponsor: TRAC- Monterey

SUMMARY: A literature review on the influence of corruption, and development of an ontology of corruption.

DEFENSE INSTITUTION BUILDING

Robert M. McNab, Associate Professor

Defense Resources Management Institute

Sponsor: Office of the Secretary of Defense–Policy (through the Center for Civil-Military Relations)

OBJECTIVE: To assist in the development of best practices in the area of defense planning, programming, and budgeting.

THE DISTRIBUTION AND FOUNDATIONS OF VIOLENCE

Robert M. McNab, Associate Professor

Defense Resources Management Institute

Sponsor: Joint Improvised Explosive Defeat Organization

SUMMARY: Research exploring the distribution of violence in Iraq, the economic incentives underlying the formation and operation of improvised explosive device (IED) networks, and the development of recommendations for stabilization and reconstruction to defeat IED networks.

DEFENSE RESOURCES MANAGEMENT INSTITUTE

A NEW PARADIGM TO ADDRESS BID PROTESTS

Francois Melese, Professor

Diana I. Angelis, Associate Professor

Pete Coughlan, Graduate School of Business and Public Policy

Max Kidalov, Graduate School of Business and Public Policy

Charles J. LaCivita, Professor and Executive Director

Defense Resources Management Institute

Raymond E. Franck, Senior Lecturer

William Gates, Associate Professor and Dean

Graduate School of Business and Public Policy

Sponsor: Office of Assistant Secretary for Acquisition, U.S. Air Force

OBJECTIVE: To examine opportunities to improve the bid protest process and enhance performance, cost, and schedule outcomes of Defense acquisition investments.

THE PEDIATRIC ASTHMA MEDICATION ADHERENCE AND COST STUDY

Anke Richter, Associate Professor

Defense Resources Management Institute

Sponsor: LTC Nancy Fagan, DVM, Ph.D., Health Program Analysis and Evaluation,
TRICARE Management Activity

OBJECTIVE: To determine whether patients receiving their asthma medications through the TRICARE Mail Order Pharmacy (TMOP), an automatic pharmacy mail-order plan available to all TRICARE participants, will incur lower costs associated with medical care system encounters and pharmaceutical costs than those obtaining their pharmacy prescriptions at the military treatment facility (MTF) on base or through other means, such as a retail pharmacy. The findings from this study may assist Department of Defense planners in developing pharmacy policy, procedures, and marketing opportunities that promote a more cost-effective balance in beneficiary utilization of military pharmacies, retail pharmacies, and the TRICARE mail order program. Status: working on final statistical analysis.

ANALYZING HEALTH BENEFITS OF CHEMOPREVENTION BEYOND THE TREATMENT PERIOD: A PROPOSED APPROACH

Jay Simon, Assistant Professor

Defense Resources Management Institute

Frank L. Meyskens, Professor

Medicine and Biological Chemistry, University of California-Irvine

Sponsor:

OBJECTIVE: To develop a methodology for evaluating potential treatments when the benefits persist beyond the treatment period but the risks do not.

SUMMARY: Most chemoprevention studies provide results after a fixed follow-up period. This research assessed the shortcomings of that method and developed an alternative approach to examine the tradeoffs between benefits and risks in more detail. Treating the benefits and risks as probabilities over time yields more actionable information than is given by the few points of data typically provided in chemoprevention studies. This method can provide a much deeper understanding of the magnitude of the associated benefits and risks of a preventive treatment. Examples are shown in the cases of calcium supplements for colorectal adenoma, isotretinoin for head and neck tumors in which long-term follow-up data is available, celecoxib to reduce occurrence of adenoma, and aspirin to reduce occurrence of colorectal cancer.

OTHER: To be submitted by the end of March 2010.

DEFENSE RESOURCES MANAGEMENT INSTITUTE

ADVANCED ANALYTICAL DECISION-MAKING RESEARCH AND WORKSHOPS

Kent D. Wall, Professor
Defense Resources Management Institute
Sponsor: Boeing Company

OBJECTIVE: To enhance the joint understanding of common analytical techniques that can be employed in the public and private sector in support of multi-criteria decision making. The focus of this research will be on the latest research in methods of multi-criteria decision making, including topics in economics, cost analysis, and uncertainty.

DIAGNOSING PERFORMANCE MANAGEMENT AND PERFORMANCE BUDGETING SYSTEMS: A CASE STUDY OF THE U.S. NAVY

Natalie J. Webb, Associate Professor
Defense Resources Management Institute
Phillip J. Candreva, Senior Lecturer
Graduate School of Business and Public Policy
Sponsor: U.S. Navy Surface Warfare Directorate

OBJECTIVE: To examine the efficiency and effectiveness of the Surface Warfare Enterprise (SWE).

SUMMARY: Using data collected from the SWE, analyzing reports and presentations to SWE and other Navy organizations, and interviewing SWE personnel, this research examined performance management and resources management issues for the Surface Warfare Enterprise. It was found that SWE personnel have made great improvements in measuring ship readiness and the costs of readiness; however, the research suggests that current Navy budgeting systems do not allow for proper tracking of costs on a per ship or per mission basis. This paper should be of interest to any public sector manager interested in improving organizational outcomes and efficiency.

PUBLICATION:

Webb, N.J. and Candreva, P., "Performance Management and Budgeting: A Case Study of the U.S. Navy's Surface Warfare Enterprise," *Public Finance and Management*, 2009 (revise and resubmit).

PRESENTATION:

Webb, N. and Candreva, P., "Exploring the Link between Performance and Resource Allocation: A Case Study of the Navy's Surface Warfare Enterprise," Western Economics Association Annual Meetings, Honolulu, Hawaii, July 2008.

TECHNICAL REPORT:

Candreva, P. and Webb, N., "Exploring the Link between Performance and Resource Allocation: A Case Study of the Navy's Surface Warfare Enterprise," 2009.

DEFENSE RESOURCES MANAGEMENT INSTITUTE

**2009
Faculty Publications
and Presentations**

DEFENSE RESOURCES MANAGEMENT INSTITUTE

JOURNALS

Amara, J. and Hendricks, A., "The Deferred Cost of War: Short and Long Term Impact of OEF/OIF on Veterans Health Care," *Defense and Security Analysis*, 25(3), 285-298, 2009.

Amara, J. and Pargac, P., "Offsets and Defense Procurement in the Czech Republic: A Case Study," *European Security*, 18(1), 63-80, 2009.

Berck, P., Lipow, J., and Plessner, Y., "Defense Planning and Fiscal Strategy," *Applied Economics Letters*, June 2009.

Everhart, S., Martinez-Vazquez, J., and McNab, R., "Corruption, Governance, Investment, and Growth in Emerging Markets," *Applied Economics*, 41 (13), 1579-1594, 2009.

Keller, L.R., Simon, J., and Wang, Y., "Multiple Objective Decision Making with Multiple Stakeholders," *Tutorials in Operations Research*, 139-155, 2009.

Lasry, A., Richter, A., and Lutscher, F., "Recommendations for Increasing the Use of HIV/AIDS Resource Allocation Models," *BMC Public Health*, 9 (Suppl. 1), S8, 2009.

Lipow, J. and Melese, F., "Does NATO Have a Role to Play in the Global Financial Crisis?" *European Security*, January 2010.

Lipow, J., Mualem, J., and Tobol, J., "Should Military Uniforms Carry the Union Label?" *Defense and Peace Economics*, February 2009.

McNab, R. and Scott, R., "Non-Lethal Weapons and the Long-Tail of Warfare," *Small Wars and Insurgencies*, 20 (1), 141-159, 2009.

Melese, F., "The Financial Crisis: A Similar Effect to a Terrorist Attack?" *NATO Review, Fourth Edition*, 2009 (<http://www.nato.int/docu/review/2009/FinancialCrisis/EN/index.htm>).

Melese, F., "Soldiers in Harm's Way," *The Economist*, March 21-27 2009.

Simon, J., "Decision Making with Prostate Cancer: A Multiple-Objective Model with Uncertainty," *Interfaces*, Vol. 39, No. 3, pp. 218-227, 2009.

Wall, K.D., "Thinking about Risk: Definition, Assessment, and Management," *Armed Forces Comptroller*, Vol. 54, No. 3, pp. 8-13, Summer 2009.

Webb, N.J. and Richter, A., "Strategy at the Crossroads: The Case of the Navy Hospital Ships," *Defense Security and Analysis*, Vol. 26, No. 2, 2010.

CONFERENCE PUBLICATIONS

Angelis, D., Dillard, J., Franck, R., and Melese, F., "Transaction Cost Economics and Cost Estimation Methodology," *Proceedings of the Sixth Annual Acquisition Research Symposium: Defense Acquisition in Transition*, Acquisition Research Program, GSBPP, Naval Postgraduate School, Vol. II, 2009.

Hansen, J.K., "Estimating Impacts of Water Scarcity Pricing," *Proceedings of the 27th International Systems Dynamics Conference*, Albuquerque, New Mexico, 26-30 July 2009.

Melese, F., "The Economic Evaluation of Alternatives," *Proceedings of the Sixth Annual Acquisition Research Symposium: Defense Acquisition in Transition*, Acquisition Research Program, GSBPP, Naval Postgraduate School, Vol. I, 2009.

DEFENSE RESOURCES MANAGEMENT INSTITUTE

PRESENTATIONS

Angelis, D.I., "Design of Experiments in Air Force Flight Testing," International Test and Evaluation Association Annual Symposium, Baltimore, Maryland, 29 September 2009.

Angelis, D.I., Dillard, J., Frank, R., and Melese, F., "Insights on Transaction Costs from a Survey of AF Program Managers," 84th Western Economic Association International Annual Conference, Vancouver, Canada, 3 July 2009.

Angelis, D.I., Dillard, J., Frank, R., and Melese, F., "Transactions Cost from a Program Manager's Perspective," 6th Annual Acquisition Research Symposium, Monterey, CA, 14 May 2009.

Hansen, J.K., "Estimating Impacts of Water Scarcity Pricing," 27th International Systems Dynamics Conference, Albuquerque, New Mexico, 26-30 July 2009.

Melese, F., "Capabilities Based Planning, and the Government of Canada's 'Strategic Review,'" presented to Canada's National Defence Headquarters, Ottawa, 2009 (invited).

Melese, F., "Economic Growth as a Basis for Modern Defense and Security Expenditures," presented to NATO staff, the Chief Economist of the U.K. MoD, several other officials, and approximately 40 representatives from countries throughout the Balkan and southeastern European region, 2009 (invited).

Melese, F., "Instruments for Measuring Accountability, Transparency, and Control of Expenditures in the Security and Defense Sector," presented to NATO staff, the Chief Economist of the U.K. MoD, several other officials, and approximately 40 representatives from countries throughout the Balkan and Southeastern European region, 2009 (invited).

Richter, A., Session Moderator for "Health Economic Analyses" at the European Forum for Evidence-Based Prevention (EUFEP) Congress, Baden, Austria, 24-26 June 2009.

Richter, A. and Thieda, P., "Health Economic Assessment of Community-Based CVD Risk-Reduction Programs," Institute for Operations Research and Management Sciences (INFORMS) Annual Meeting, San Diego, California, 11-14 October 2009.

Richter, A. and Thieda, P., "A Health Economic Model for Preventive Interventions in Lower Austria," European Forum for Evidence-Based Prevention (EUFEP) Congress, Baden, Austria, 24-26 June 2009.

Simon, J., "Life Decisions with Health Outcomes," INFORMS Western Regional Conference, Tempe, Arizona, 23-24 April 2009.

Simon, J., "Reference-Dependent Expected Utility Models," INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

MEETING ABSTRACT

Amara, J., "Economic and Security Implications of Military Stabilization Efforts: The Iraq Surge as a Case Study," 84th Annual Conference of the Western Economic Association International, Vancouver, Canada, 30 June-3 July 2009.

Amara, J., "Scale Invariance in the 2003-2008 Iraq Conflict," 84th Annual Conference of the Western Economic Association International, Vancouver, Canada, 30 June-3 July 2009.

DISCUSSANT

Meade, D., Soyong Chong, S., and Summers, G., "Importing Guns and Butter: Providing for the Common Defense in an Era of Globalization," 84th Annual Conference of the Western Economic Association International, Vancouver, Canada, 30 June-3 July 2009 (working paper).

CONTRIBUTIONS TO BOOKS

Amara, J., "U.S. Jordan Bilateral Relations," *Handbook of U.S.-Middle East Relations*, R. Looney (Ed.), London: Routledge, 2009.

Melese, F., "A Brinkmanship Game Theory Model of Terrorism," Part V in *Mathematical Methods in Counterterrorism*, N. Memon, J. Farley, and T. Rosenorn (Eds.), New York: Springer-Verlag/Wien, pp. 319-332, 2009.

BOOK REVIEWS

Lipow, J., Review of "Castle, Battles, and Bombs: How Economics Explains Military History," *Defense and Peace Economics*, October 2009.

TECHNICAL REPORTS

Angelis, D.I., Dillard, J., Frank, R., and Melese, F., "Transaction Costs from a Program Manager's Perspective," Acquisition Research Sponsored Report Series, NPS-AM-09-142, 28 September 2009.

Melese, F., Angelis, D.I., Coughlan, P., Franck, R., Gates, W., Kidalov, M., and LaCivita, C.J., "A New Paradigm to Address Bid Protests," Submitted to the Office of Assistant Secretary for Acquisition, U.S. Air Force, January 2010.

**DEPARTMENT OF NATIONAL
SECURITY AFFAIRS**

**DOUGLAS PORCH
CHAIRMAN**

NATIONAL SECURITY AFFAIRS

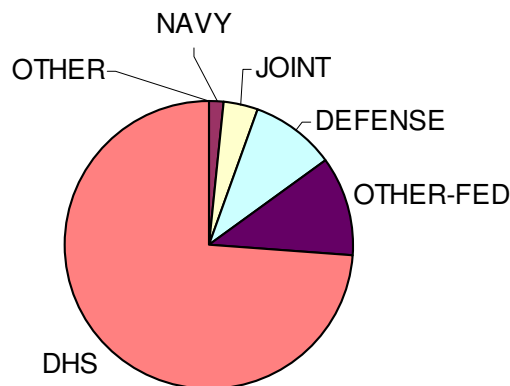
OVERVIEW:

The Naval Postgraduate School's (NPS) Department of National Security Affairs (NSA) specializes in the study of international relations, security policy, and regional studies. NSA is unique because it brings together outstanding faculty, students from the Army, Air Force, Navy, Marines, National Guard, and various civilian agencies, and scores of international officers from dozens of countries for the sole purpose of preparing tomorrow's military and civilian leaders for emerging security challenges.

The faculty is made up of approximately fifty professors and instructors. Every member of the faculty is a specialist in an aspect of security studies or in the politics and culture of a specific region. The faculty members are drawn from the top Ph.D.-granting institutions in history, political science, and economics. They are deeply involved in cutting-edge academic research and publication, enhancing their ability to provide superior, graduate-level education in support of U.S. national security interests. The study of security studies at NPS has been listed among the top ten universities in the 2006-2007 Faculty Scholarly Productivity (FSP) Index in the International Affairs and Development category. The faculty pride themselves on being responsive to the evolving needs of research and curricula sponsors, which creates a dynamic and exciting environment for students. Unlike other graduate programs, faculty, not research assistants, actually teach all classes.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of National Security Affairs is provided below:



Size of Program: \$24M

NATIONAL SECURITY AFFAIRS

Douglas Porch
Professor and Chairman
831-656-1038
rdporch@nps.edu

Harold A. Trinkunas
Associate Professor and Chairman, Deputy Director for Academic Affairs
831-656-2863
Hatrinku@nps.edu

Donald Abenheim
Associate Professor
831-656-3171
dabenheim@nps.edu

Anne Marie Baylouny
Associate Professor
831-656-2739
ambaylou@nps.edu

Thomas C. Bruneau
Distinguished Professor
831-656-1037
tbruneau@nps.edu

Col Mark Chakwin, USA
Foreign Area Officer Chair/
Senior Army Representative
831-656-3654
mbchakwi@nps.edu

Victoria Clement
Assistant Professor
831-656-3293
vscllemen@nps.edu

Anne L. Clunan
Associate Professor
831-656-2904
alclunan@nps.edu

Eric Dahl
Assistant Professor
831-656-3168
ejdahl@nps.edu

Zachary S. Davis
Research Professor
831-656-1036
zsdavis@nps.edu

Guido de la Vega
Professor
831-656-2744
gdelaveg@nps.edu

Kenneth R. Dombroski
Lecturer
831-656-3219
kdombroski@nps.edu

Sophal Ear
Assistant Professor
510-996-6911
sear@nps.edu

Scott Field
Lecturer
590-6976
safield@nps.edu

Christian Ford
Lecturer/Professor
ceford@nps.edu

Jeanne Giraldo
Visiting Professor
831-656-2990
jkgirald@nps.edu

Mohammed M. Hafez
Associate Professor
831-656-1038
mmhafez@nps.edu

CAPT Jennith Hoyt, USN
Senior Intelligence Officer
831-656-2288
jehoyt@nps.edu

Wade Huntley
Senior Lecturer
wlhuntle@nps.edu

Maiah Jaskoski
Assistant Professor
831-656-3167
majaskos@nps.edu

Scott Jasper
CAPT, USN (Ret.),
CEO and Lecturer
Center for Civil-Military
Relations
831-656-2913
sejasper@nps.edu

Tom Johnson
Research Professor
831-656-3190
thjohnso@nps.edu

Abbas Kadhim
Assistant Professor
510-847-5983
akkadhim@nps.edu

Paul Kapur
Associate Professor
831-656-3898
spkapur@nps.edu

Feroz Khan
Visiting Faculty
831-656-3043
fhkhan@nps.edu

Jeffrey W. Knopf
Visiting Associate Professor
831-656-7729
jwknopf@nps.edu

Letitia L. Lawson
Senior Lecturer
831-656-2744
lllawson@nps.edu

Sandi Leavitt
Executive Director, Center
for Contemporary Conflict
831-656-3680
srleavit@nps.edu

NATIONAL SECURITY AFFAIRS

Theodore G. Lewis
Professor
831-656-2830
tlewis@nps.edu

Maria Jose Rasmussen
Associate Professor
831-656-3673
mrasmussen@nps.edu

LCDR Thomas Statler, USN
Instructor
831-656-3519

Robert E. Looney
Distinguished Professor
831-656-3484
relooney@nps.edu

Dirk Rogalski
Visiting Lecturer
831-656-1036
dhrogals@nps.edu

Houda Tarabishi
Lecturer
831-656-2562
htarabis@nps.edu

Tristan Mabry
Research Assistant Professor
831-656-7528
tjmabry@nps.edu

James Russell
Senior Lecturer
831-656-2109
jarussel@nps.edu

Mikhail Tsyppin
Associate Professor
831-656-2218
mtsypkin@nps.edu

Michael Malley
Assistant Professor
831-656-2409
msmalley@nps.edu

Robin Sakoda
Lecturer
831-656-3168
rhsakoda@nps.edu

Christopher P. Twomey
Assistant Professor and
Associate Chair for Research
831-656-3543
ctwomey@nps.edu

Alice L. Miller
Senior Lecturer
831-656-2143
hlmille1@nps.edu

Zachary Shore
Associate Professor
831-656-3358
zshore@nps.edu

Robert J. Weiner
Assistant Professor
831-656-3952
rjweiner@nps.edu

James C. Moltz
Associate Professor
831-656-1039
jcmoltz@nps.edu

Scott N. Siegel
Assistant Professor
831-656-3294
snsiegel@nps.edu

James J. Wirtz
Professor, Dean of SIGS
831-656-3483
jwirtz@nps.edu

Daniel J. Moran
Professor
831-656-2059
djmoran@nps.edu

Arturo C. Sotomayor
Assistant Professor
831-656-2798
acsotoma@nps.edu

David S. Yost
Professor
831-656-2579
dyost@nps.edu

Jessica Piombo
Associate Professor
831-656-2831
[jrpiombo@nps.edu](mailto:jрпиombo@nps.edu)

Robert Springborg
Professor
831-656-3631
rdspring@nps.edu

NATIONAL SECURITY AFFAIRS

HIZBULLAH IN THE TRI-BORDER AREA AND LATIN AMERICA

**Anne Marie Baylouny, Assistant Professor
Department of National Security Affairs
Sponsor: Office of the Secretary of Defense**

OBJECTIVE: To produce an overview paper on Hizbullah in the tri-border region and Latin America. This will include what we know and what we need to know, and will develop the conceptual and theoretical framework for the rest of the project. Findings will be presented at a conference determined in combination with the sponsor.

ITAC SUPPORT FOR THE JFSSPP FOR THE FAOWEB HARDWARE, SOFTWARE

**Col Mark Chakwin, USA, Foreign Area Officer Chair/Senior Army Representative
Department of National Security Affairs
Sponsor: Defense Language Office**

OBJECTIVE: To define partner roles and responsibilities in the creation of the Joint Foreign Area Officer (FAO) Skill Sustainment Pilot Program (Joint FAO SSPP), hereafter referred to as the "Pilot Program." The areas of responsibilities and relationships presented herein will guide program implementation. This agreement is subject to the provisions of all applicable statutes, regulations, directives, policies, and procedures of the Department of Navy and the Department of Defense in accordance with U.S. government laws, policies, and practices.

THE JOINT FOREIGN AREA OFFICER SKILL SUSTAINMENT PILOT PROGRAM

**Col Mark Chakwin, USA, Foreign Area Officer Chair/Senior Army Representative
Department of National Security Affairs
Sponsor: Defense Language Office**

OBJECTIVE: To define partner roles and responsibilities in the creation of the Joint Foreign Area Officer (FAO) Skill Sustainment Pilot Program (Joint FAO SSPP), hereafter referred to as the "Pilot Program." The areas of responsibilities and relationships presented herein will guide program implementation. This agreement is subject to the provisions of all applicable statutes, regulations, directives, policies, and procedures of the Department of Navy and the Department of Defense in accordance with U.S. government laws, policies, and practices.

PREVENTING TERRORIST ATTACKS: INTELLIGENCE WARNING AND POLICY RESPONSE

**Eric Dahl, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School**

OBJECTIVE: This research is aimed at the intersection of intelligence and terrorism. The specific goal is to help understand how intelligence information can be better collected and used to prevent terrorist attacks. More generally, the research is designed to contribute to the study of intelligence by improving understanding of the factors that contribute to intelligence failure and success, and to the field of terrorism studies by focusing on the under-studied area of lessons that can be learned from failed terrorist attacks.

NATIONAL SECURITY AFFAIRS

COUNTRY X CONSULTATIONS

Zachary S. Davis, Research Professor
Department of National Security Affairs
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: To bring high-level United States academics, policymakers, intelligence analysts, and military experts together to examine the growing role of interdiction in confronting nuclear proliferation networks. The Networks and Interdiction Conference follows upon nascent plans to construct an interdiction curriculum at the Naval Postgraduate School.

THE INTERDICTION STUDIES PROGRAM – FY2009

Zachary S. Davis, Research Professor
Department of National Security Affairs
Sponsor: National Counter Proliferation

SUMMARY: The Navy is a key partner in national interdiction activities. Because of its obvious strength in national security education on research, the Naval Postgraduate School is the optimal institution to support and educate training and research programs to aid the national counter-proliferation interdiction mission.

TOWARDS EFFECTIVE EMERGING INFECTIOUS-DISEASES SURVEILLANCE: THE CASES OF CAMBODIA AND INDONESIA AND THE EXPERIENCE OF NAMRU-2

Sophal Ear, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To draft a report describing the barriers to zoonotic virus surveillance in animals using the case study method and comparing Cambodia and Indonesia and the respective experience of Navy Medical Research Unit Two.

TRADING DEMOCRACY FOR SECURITY: GOVERNING CAMBODIA AFTER THE UNITED STATES

Sophal Ear, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School

OBJECTIVE: To deepen the understanding of post-conflict reconstruction, democratization, and security. To refine the principal investigator's (PIs) existing theoretical and empirical work; to identify additional, promising cases to examine; to develop the chapters of an already existing book proposal based on the PI's dissertation, which has garnered supportive feedback from Cornell University Press; to support the writing of an article-length version of research to be presented at a public management conference in Singapore in June 2008; and to contribute a chapter to an edited volume entitled *In Search of Political Legitimacy in Cambodia*, which will come out in 2009.

DEBATING JIHAD: IDEOLOGICAL DIVIDES IN THE RADICAL ISLAMIST MOVEMENT

Mohammed M. Hafez, Associate Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School

OBJECTIVE: To explore the ideological debates that divide global jihadists. This research is a contribution to the broader U.S. objective of engaging in a battle of ideas with radical Islamism. The aim is to gain insight into how radical Islamists associated with the jihadi Salafist strand rationalize their extremist

NATIONAL SECURITY AFFAIRS

worldviews in relation to ideological and theological challenges posed by mainstream and other radical Islamists. The goal is to produce a book that explores the contemporary history of intra-jihadists' ideological disputes and suggest ways for the United States to succeed in its ideological engagement with transnational radical Islamists.

SUPPORT FOR NAVAL INTELLIGENCE RESEARCH AND EDUCATION

CAPT Jennith Hoyt, USN, Senior Intel Officer

Department of National Security Affairs

Sponsor: Office of Naval Intelligence

OBJECTIVE: To provide resources for Navy 1630 (Intelligence Officer) research and education, and to provide facility support to ensure Navy 1630 student education.

LATIN AMERICAN MILITARY MISSIONS AND THE BLURRING OF THE PUBLIC-PRIVATE DIVIDE IN NATURAL RESOURCE SECTORS

Maiah Jaskoski, Assistant Professor

Department of National Security Affairs

Sponsor: Naval Postgraduate School

OBJECTIVE: To conduct research on security services performed by public security forces for natural resource sectors in Latin America.

A CULTURAL MODELING CONFERENCE

Thomas Johnson, Research Professor

Department of National Security Affairs

Sponsor: Joint Warfare Analysis Center

OBJECTIVE: To organize a conference exploring cultural-conflict modeling from multiple perspectives, including quantitative and qualitative approaches. Some of the objectives of this conference are: to identify the best practices and the most efficient methods for cultural modeling; to unravel the anthropological perspective to data gathering; to examine assumptions utilized in cultural modeling; and to compare and contrast different modeling methodologies (i.e., agent-based models).

DEVELOPING IMPROVISED EXPLOSIVE DEVICES COUNTER-NARRATIVES

Thomas Johnson, Research Professor

Department of National Security Affairs

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: Presently, 49% of U.S. casualties in Afghanistan are caused by improvised explosive devices (IEDs) and EFPs, and that percentage is growing. IEDs and EFPs are relatively new weapons in Afghanistan. In order to effectively counteract IEDs in Afghanistan, it is essential to understand their human masters and the narratives that drive them, and to develop successful counter-narrative techniques.

This study will analyze IED narratives in Afghanistan from a variety of sources, including Taliban press releases and night letters (shabnamah), local media, and, when possible, the messages and accounts of the bombers themselves. While sacrifice and martyrdom are virtues among Afghan jihadi narratives, deliberate suicide (which accounts for approximately ten percent of IED attacks in Afghanistan) is culturally anathema. Traditionally, anonymous attacks (such as roadside bombs) were similarly shunned. Just as anti-coalition militia seek to incorporate these tactics into the culture of war in Afghanistan, those tactics can be disassociated, shamed, and vilified through counter-narratives.

This project will identify the insurgent discourses making IEDs culturally acceptable, analyze them, and disassemble them. If the tactics of IEDs and suicide can be effectively demonstrated as being culturally unacceptable, support for these tactics among the rural populations can be substantially reduced.

NATIONAL SECURITY AFFAIRS

JAWAC RESEARCH AND DATA SUPPORT

Thomas Johnson, Research Professor
Department of National Security Affairs
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: To provide the Joint Warfare Analysis Center with Middle East, South Asia, and central Asia-specific research and expertise to support its mission. The project team, under the leadership of Professor Thomas Johnson, will consist of the Program for Culture and Conflict Studies research staff and selected graduate students from the Department of National Security Affairs at the Naval Postgraduate School.

JPM IS JEM 1.1 DATA PANEL REVIEW SUPPORT

Thomas Johnson, Research Professor
Department of National Security Affairs
Sponsor: Information Systems Joint Program Office

OBJECTIVE: To provide a detailed assessment of the appropriateness of the data included with the chemical (militarized and TIC/TIM) material files provided with the JEM 1.1 code – the future version of JEM that implements HPAC 5.0 SP1 components.

THE NAVAL POSTGRADUATE SCHOOL AFGHAN COIN WEB PORTAL FY08 PROGRAM FOR CULTURE AND CONFLICT STUDIES: A WEB GAZETTEER FOR THE 21ST CENTURY

Thomas Johnson, Research Professor
Department of National Security Affairs
Sponsor: Office of the Secretary of Defense

OBJECTIVE: To provide ongoing research and dissemination of socio-cultural/human-terrain information on Afghanistan via an open-source web portal (www.NPS.edu/programs/ccs) to provide comprehensive assessments of tribal and clan networks in coordination with ongoing COIN operations and needs; and to supply deployed forces with accurate information in a timely manner via the web portal and by responding to requests for information.

THE NAVAL POSTGRADUATE SCHOOL COIN WEB PORTAL

Thomas Johnson, Research Professor
Department of National Security Affairs
Sponsor: Office of the Secretary of Defense

OBJECTIVE: To develop and publish research of socio-cultural/human-terrain information on Pakistan, particularly the Federally Administered Tribal Areas (FATA) and the North West Frontier Province (NWFP) via an open-source web portal. Some of the objectives of this project are to provide timely and current ethnographic, socio-cultural, and geospatial information to deployed units, analysis teams, and other consumers via an open-source platform; to expose and educate deploying and deployed units with necessary human-terrain information prior to and during COIN operations; to support military units, government, and nongovernment organizations involved with development activities in Afghanistan and Pakistan with requested information on the tribal, ethnic, and political context; and to act as a reach-back on security, political, economic, and other human-terrain issues in Pakistan and Afghanistan.

NATIONAL SECURITY AFFAIRS

SSA DATA MANAGEMENT AND DATA MODEL SUPPORT

Thomas Johnson, Research Professor

Department of National Security Affairs

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To ensure continued support for the implementation of the Chemical, Biological, Radiological, Nuclear (CBRN) Data Model across Joint Program Executive Office (JPEO) Chemical Biological Defense (CBD) in support of the Joint Project Manager, Information Systems, Software Support Activity (JPMIS SSA).

CAPTURING THE NARRATIVE – THE 1991 UPRISING IN IRAQ

Abbas Kadhim, Assistant Professor

Department of National Security Affairs

Sponsor: American Academic Research Institute in Iraq

SUMMARY: Recipient of 2009 U.S. fellowship award.

THE EFFECTS OF NUCLEAR WEAPONS PROLIFERATION ON SOUTH ASIAN SECURITY

Paul Kapur, Associate Professor

Department of National Security Affairs

Sponsor: Naval Postgraduate School

OBJECTIVE: To continue the study of the effect of nuclear weapons proliferation on the South Asian security environment; to complete a book (under contract with Columbia University Press) in which the principal investigator debates another prominent South Asia scholar (Sumit Ganguly of Indian University) on this question; to travel to South Asia and Washington to conduct research and interviews and present work at Indian think-tanks.

THE U.S.-INDIA STRATEGIC PARTNERSHIP IV

Paul Kapur, Associate Professor

Department of National Security Affairs

Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To examine issues affecting long-term strategic cooperation between the United States and India by examining potential areas for strategic cooperation, assessing challenges, and formulating ideas for new strategies to enhance U.S.-India strategic ties over the next decade.

ASSURANCE STRATEGIES AND NATIONAL SECURITY

Jeffrey Knopf, Associate Professor

Department of National Security Affairs

Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To convene a small group of scholars for a one-day conference to study the use of security assurances in national security strategy. The goals are to clarify the nature of assurance strategies, to identify the circumstances under which they are an appropriate tool of statecraft, and to identify the factors that most strongly affect national security.

NATIONAL SECURITY AFFAIRS

DETERRENCE AFTER 9/11: NEW DEVELOPMENTS IN THEORY AND PRACTICE

Jeffrey Knopf, Associate Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School

OBJECTIVE: To evaluate whether deterrence is still applicable and how best to employ it against post-9/11 threats. This will be done by examining both post-9/11 academic research on deterrence and the role of deterrence in U.S. strategy as it has evolved since 9/11.

AREA STUDIES SEMINARS
Sandi Leavitt, Executive Director,
Center for Contemporary Conflict
Department of National Security Affairs
Sponsor: National Security Agency

OBJECTIVE: To provide two topically relevant seminars for the purpose of presenting recent research.

INITIATIVE: DEVELOPING MULTI-MODAL TRANSPORTATION-SECURITY NETWORKS

Theodore Lewis, Professor
Department of National Security Affairs
Sponsor: Transportation Security Agency

OBJECTIVE: This research involves a “learn by doing” project within the northwest region that will help federal security directors become more effective in their new roles in the multi-modal transportation environment. The project will build a network, or “megacommunity” as it is called in the research literature, to bring multi-modal transportation groups together in a working relationship to enhance specific security problems or challenges across various sectors. Building this network is a first step in solving specific problems and not simply a venue for discussing lofty security concepts. This effort will take the Transportation Security Agency (TSA) from just knowing the right local contacts in a crisis response to developing a network that looks strategically, collectively, and proactively at improving security. As a problem-solving network, participating groups, including the TSA, will learn how to organize and use their assets in a joint strategy.

MARITIME SECURITY RISK ASSESSMENT METHODOLOGY (MSRAM) INDEPENDENT VERIFICATION AND VALIDATION

Theodore Lewis, Professor
Department of National Security Affairs
Sponsor: United States Coast Guard

OBJECTIVE: Sponsored maritime security risk assessment methodology (MSRAM) independent verification and validation (IV&V) for the United States Coast Guard.

SPONSORED HOMELAND DEFENSE AND SECURITY LEADERSHIP DEVELOPMENT

Theodore Lewis, Professor
Department of National Security Affairs
Sponsor: Department of Homeland Security

OBJECTIVE: To refine the development and delivery of the homeland security (HS) graduate program nationwide. The program: 1) assist local, state, and federal leaders across all disciplines to develop the strategies, policies, and organizational elements (including civil-military and interagency and intergovernmental cooperation) needed to defeat terrorism; and create a “multiplier effect” to maximize federal investment by sharing program content and research results with organizations across the nation to

NATIONAL SECURITY AFFAIRS

build national HS preparedness through education. The FY09 budget request is based upon the Department of Homeland Security FEMA-National Preparedness Directorate (NPD) guidance to develop and conduct “cutting edge” graduate programs for senior homeland security local, state, and federal officials. The core CHDS instructional program is the homeland security Master’s degree program. This program continues to evolve to build the national capacity for homeland security.

SPONSORED HOMELAND DEFENSE AND SECURITY LEADERSHIP DEVELOPMENT FOR DHS/FEMA – ADD A GRANT PROGRAMS DIRECTORATE FELLOW

Theodore Lewis, Professor
Department of National Security Affairs
Sponsor: Department of Homeland Security

OBJECTIVE: To refine the development and delivery of the homeland security (HS) graduate program nationwide. This program will assist local, state, and federal leaders across all disciplines to develop the strategies, policies, and organizational elements (including civil-military and interagency and intergovernmental cooperation) needed to defeat terrorism; and create a “multiplier effect” to maximize federal investment by sharing program content and research results with organizations across the nation to build national HS preparedness through education. The FY09 budget request is based upon the Department of Homeland Security FEMA-National Preparedness Directorate (NPD) guidance to develop and conduct “cutting edge” graduate programs for senior homeland security local, state, and federal officials. The core CHDS instructional program is the homeland security Master’s degree program. This program continues to evolve to build the national capacity for homeland security.

NETWORKS AND INTERDICTION - 1

Michael Malley, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Sea Systems Command

OBJECTIVE: To bring high-level United States academics, policymakers, intelligence analysts, and military experts together to examine the growing role of interdiction in confronting nuclear proliferation networks. The Networks and Interdiction Conference follows upon nascent plans to construct an interdiction curriculum at the Naval Postgraduate School.

PREPARING FOR NUCLEAR EXPANSION IN SOUTHEAST ASIA: A FRAMEWORK FOR EFFECTIVE COOPERATION AND ENHANCING SECURITY

Michael Malley, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To assess the proliferation challenges posed by the expansion of civilian nuclear capabilities in Southeast Asia, and to identify ways of meeting those challenges. In particular, this research will examine: the current state and future prospects in the region for the development of civilian nuclear programs; government compliance with international nuclear agreements; Asian initiatives to address nuclear safety and security; and the national regulatory capacity to reduce the extent of ungoverned spaces in the region.

NATIONAL SECURITY AFFAIRS

ASIA'S RISING SPACE POWERS
Clay Moltz, Associate Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School

OBJECTIVE: To continue research on a book manuscript and to develop relationships with future collaborators.

**SUPPORTING COLLABORATION BETWEEN THE NASA AMES RESEARCH CENTER AND
THE NAVAL POSTGRADUATE SCHOOL: THE SPACE FUTURES WORKING GROUP**

Clay Moltz, Associate Professor
Department of National Security Affairs
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: To conduct a series of activities in support of the National Aeronautics and Space Administration ARC during the 12-month period from July 2008 to June 2009, with completion of deliverables due by 30 June 2009. The principal investigator will: 1) help facilitate cooperation between ARC and the Naval Postgraduate School in education and research relevant to future U.S. space policy; 2) chair and help manage the activities of the Space Futures Working Group; and 3) complete four short reports on issues affecting future U.S. space policy (in consultation with Robert H. Schingler and Dr. William S. Marshall).

**UNDERSTANDING AND RESPONDING TO CONFLICT IN AFRICA: THE IMPLICATION OF
FOCUSING ON ROOT CAUSES VERSUS COMPLEX END-STATES**

Jessica Piombo, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To evaluate a conundrum facing policymakers in the U.S. government and elsewhere, whether to focus on root causes or complex problems when devising policy to deal with violent conflict. This research will explicitly focus on the twin issues of what approach policy-makers should take and what tradeoffs the choice taken then creates. This analysis will be conducted through a case study of a specific conflict in Africa, focusing on the intersection of various security challenges in one conflict, and analyzing at what level the conflict should be understood in order to help inform policy decisions across the range of U.S. government agencies that address issues of African security. The fundamental question to be addressed is: what are the tradeoffs of different approaches (foundations versus end-states) to understanding and dealing with the security environment? Related to this, what are the explicit linkages between sets of security threats and what complex security vulnerabilities do those create?

THE FUTURE OF THE NONPROLIFERATION TREATY CONFERENCE

James Russell, Senior Lecturer
Department of National Security Affairs
Sponsor: Weapons Intelligence, Nonproliferation, and Arms Control Center

SUMMARY: The Weapons Intelligence, Nonproliferation, and Arms Control Center (WINPAC) will commission the Center for Contemporary Conflict at the Naval Postgraduate School in Monterey, California, to bring together intelligence professionals and interested experts from appropriate cleared services to analyze the effectiveness of nuclear non-proliferation instruments. This project is one part of a broadly-based study by WINPAC to assess the long-term utility of the nuclear non-proliferation regime and its supporting instruments.

NATIONAL SECURITY AFFAIRS

IRAN QUINT

James Russell, Senior Lecturer

Department of National Security Affairs

Sponsor: Office of Middle Eastern and North African Analysis

OBJECTIVE: The CIA will commission the Center for Contemporary Conflict (CCC) at the Naval Postgraduate School (NPS) in Monterey, California, to bring together intelligence professionals from the United States, Australia, Canada, New Zealand, and the United Kingdom from appropriate cleared services to discuss Middle East security regional issues.

NUCLEAR PROLIFERATION IN THE MIDDLE EAST

James Russell, Senior Lecturer

Department of National Security Affairs

Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To convene a conference in Dubai or another regional venue that examines the role of extended deterrence and security guarantees by outside powers in affecting nuclear proliferation.

NUCLEAR SMUGGLING AND THE GLOBAL PROLIFERATION LANDSCAPE

James Russell, Senior Lecturer

Department of National Security Affairs

Sponsor: Weapons Intelligence, Nonproliferation, and Arms Control Center

OBJECTIVE: The Weapons Intelligence, Nonproliferation, and Arms Control Center will commission the Center of Contemporary Conflict at the Naval Postgraduate School in Monterey, California, to bring together intelligence professionals from appropriate cleared services to discuss, in a classified setting, the global proliferation landscape and the implications of nuclear smuggling.

NUCLEAR STABILITY SOUTH ASIA, TRACK II

James Russell, Senior Lecturer

Department of National Security Affairs

Sponsor: Department of Energy

OBJECTIVE: To examine issues affecting long-term strategic cooperation between the United States and India and between the United States and Pakistan by examining potential area for strategic cooperation, assessing challenges, and formulating ideas for new strategies to enhance strategic ties over the next decade.

PROLIFERATION PATHWAYS AND SUPPLIER NETWORKS

James Russell, Senior Lecturer

Department of National Security Affairs

Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To examine the organization, technologies, processes, and deception-and-denial practices of past and current networks involved in the procurement of weapons of mass destruction (WMD) and/or its related technology, expertise, or materials; to explore commonalities and differences among networks; to assess if there have been evolutionary or revolutionary trends over time; and to estimate the likely near- and mid-term landscape that policymakers will have to navigate as they cope with combating WMD.

NATIONAL SECURITY AFFAIRS

PUBLIC POLICY AND NUCLEAR-THREATS TRAINING PROGRAM/PROLIFERATION PATHWAYS IN ASIA

James Russell, Senior Lecturer
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To examine current world-proliferation pathways in the Asia-Pacific region and the threats they pose to U.S. security and interests. Top experts from within and outside the U.S. will assess options for improving U.S. strategies and policies to counter the threats posed by the proliferation of weapons of mass destruction and terrorism.

SOUTH ASIAN SECURITY 2010

James Russell, Senior Lecturer
Department of National Security Affairs
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: The DDNI/A/NIC will commission the Center for Contemporary Conflict at the Naval Postgraduate School in Monterey, California, to bring together intelligence professionals from appropriate cleared services to discuss long term security in South Asia.

THE U.S.-INDIA STRATEGIC PARTNERSHIP II: A TRACK TWO DIALOGUE FOR LONG- TERM SECURITY COOPERATION

James Russell, Senior Lecturer
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To examine issues affecting long-term strategic cooperation between the United States and India by examining potential area for strategic cooperation, assessing challenges, and formulating ideas for new strategies to enhance U.S.-India strategic ties over the next decade.

THE U.S.-PAKISTAN STRATEGIC PARTNERSHIP: A TRACK TWO DIALOGUE FOR LONG- TERM SECURITY COOPERATION

James Russell, Senior Lecturer
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: The training program and conference will examine current world-proliferation pathways in the Asia-Pacific region and the threats they pose to U.S. security and interests. Top experts from within and outside the U.S. will assess options for improving U.S. strategies and policies to counter the threats posed by the proliferation of weapons of mass destruction and terrorism.

THE U.S.-PAKISTAN STRATEGIC PARTNERSHIP III: TRANSITION AND STABILITY IN A NUCLEAR-ARMED REGION

James Russell, Senior Lecturer
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To bring high-level Pakistani and U.S. experts together to examine potential avenues for long-term, strategic cooperation between the United States and Pakistan. This will be the third in a series of workshops examining issues critical to U.S.-Pakistan relations.

NATIONAL SECURITY AFFAIRS

THE 2008 MONTEREY PROLIFERATION SEMINAR: A NET ASSESSMENT OF ISSUES AND POLICY CHALLENGES

James Russell, Senior Lecturer
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: The principal investigator and invited subject matter experts will convene a conference at the Naval Postgraduate School in Monterey, California, in June 2008 to make a comprehensive net assessment of global counter-proliferation efforts since 2000. This conference will follow up on topics covered during past conferences, examine the successes and failures of U.S. and international policies, and draw conclusions about the future of proliferation and counterterrorism.

THE 2009 PROLIFERATION SEMINAR

James Russell, Senior Lecturer
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To convene the CCC-ASCO Annual Proliferation Seminar in the summer of 2009 in Monterey. This conference has become a flagship event in the CCC-ASCO partnership.

THE PEACE SOLDIER FROM THE SOUTH: FROM PRAETORIANISM TO PEACEKEEPING

Arturo C. Sotomayor, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School

OBJECTIVE: This research lies at the intersection of international relations and comparative politics. The goal is to examine the impact of United Nations peacekeeping participation on the civil-military relations of democratizing states. Specifically, this project will analyze how the incorporation of the military into peace operations has contributed, or not, to increase civilian control of the armed forces in Argentina, Brazil, Chile, and Uruguay

GLOBALIZATION RESISTED: THE MIDDLE EAST AND NORTH AFRICA IN SEARCH OF DEVELOPMENT MODELS

Robert Springborg, Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School

OBJECTIVE: To explain why globalization has not impacted the political economies of the Middle East and North Africa, either as anticipated prior to 9/11 or in fashions closely analogous to those observed in other developing regions. To that end, this research will consider the impacts of financial flows and their interactions with political and cultural factors, including the global war on terror and the rise of political Islam. The goal is to identify anticipated changes in global capital flows into the region and the varying abilities of the region's political economies to deal with those changes. This project will result in a successor volume to Clement M. Henry and Robert Springborg's *Globalization and the Politics of Development in the Middle East*.

NATIONAL SECURITY AFFAIRS

INSIDE RUSSIA – EMERGING TRENDS AND POLICY IMPLICATIONS

**Mikhail Tsypkin, Associate Professor
Department of National Security Affairs
Sponsor: Foreign Service Institute**

OBJECTIVE: To participate on a panel discussing Russian internal-political dynamics and civil-military affairs within the “Inside Russia Emerging Trends and Foreign Policy Implementations” roundtable to be held at the Foreign Service Institute in Arlington, Virginia, on 26 March 2009.

THE U.S.-RUSSIA STUDY GROUP ON STRATEGIC CRISIS MANAGEMENT

**Mikhail Tsypkin, Associate Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency**

OBJECTIVE: This year’s research will focus on recent changes in the U.S.-Russian strategic relationship, with specific emphasis on the implications of these changes for arms control dialogue after START expires. In addition, this year’s project will provide a forum for continued high-level discussions on previously assessed topics that have risen in prominence over the past six months, including work performed by the Bilateral Study Group involving moving beyond MAD; avenues for jointly combating WMD terrorism; response to third-party ballistic-missile threats; and cooperation in command and control and joint data exchange.

A JOINT DEFENSE CAPABILITIES ASSESSMENT CONFERENCE IN TAIWAN

**Christopher Twomey, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Security Cooperation Agency**

THE NAVAL POSTGRADUATE SCHOOL ASIA CONFERENCE

**Christopher Twomey, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Security Cooperation Agency, Office of the Secretary of Defense**

OBJECTIVE: The Center for Contemporary Conflict (CCC) will host the Monterey talks in coordination with OSD-(Taiwan) in July 2008. The conference builds on past CCC research efforts.

THE U.S.-CHINA STRATEGIC DIALOGUE

**Christopher Twomey, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency**

SUMMARY: Fifth annual U.S.-China strategic dialogue.

THE U.S.-CHINA STRATEGIC DIALOGUE, PHASE IV

**Christopher Twomey, Assistant Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency**

OBJECTIVE: To continue a track-two dialogue on Sino-American strategic-nuclear issues in order to improve mutual understanding and reduce the possibility of political or military conflict between the People’s Republic of China and the United States.

NATIONAL SECURITY AFFAIRS

COMPETITION DYNAMICS AND PARTY SYSTEM EVOLUTION IN JAPAN, AND HOST-NATION POLITICS OF U.S. BASES IN ASIA

Robert Weiner, Assistant Professor
Department of National Security Affairs
Sponsor: Naval Postgraduate School

OBJECTIVE: To complete a book manuscript on party competition in Japan; to write articles on related subject matters and on the Democratic Party in Japan; to initiate a new research program on the comparative politics of U.S. military bases in Asia; to conduct on-campus research and fieldwork abroad; and to develop contacts for future research support.

ARMS CONTROL FUTURE ISSUES

James Wirtz, Professor
Department of National Security Affairs
Sponsor: Department of the Navy Strategic Systems Programs

OBJECTIVE: To provide support to the Navy Treaty Implementation Program (NTIP) by supporting research on the future of arms control, deterrence, and support to NTIP treaty exercises.

EUROPEAN SECURITY AND NATO NUCLEAR POLICY

David S. Yost, Professor
Department of National Security Affairs
Sponsor: Office of the Assistant Secretary of Defense

OBJECTIVE: To advance the understanding of European security-policy developments, notably with regard to NATO nuclear-weapons policy. This includes matters such as nuclear deterrence doctrine in the Alliance and policy debates in major NATO European countries.

EXTENDED DETERRENCE IN THE 21ST CENTURY

David S. Yost, Professor
Department of National Security Affairs
Sponsor: Deputy Assistant to the Secretary of Defense (Nuclear Matters),
Office of the Secretary of Defense

OBJECTIVE: To advance understanding of the evolving requirements for U.S. extended deterrence in the 21st century, notably with regard to U.S. nuclear weapons. This includes matters such as nuclear deterrence doctrine and corresponding policy issues.

SUMMARY: Changes in the international security environment since the collapse of the Soviet Union in 1989-1991 have created a new context for the analysis of U.S. alliance policy and theories of extended deterrence. Issues include the evolving purposes of the U.S. nuclear force posture and security commitments to allies, questions of doctrine and declaratory policy, and the future of relevant international arms-control regimes. The continuing proliferation of weapons of mass destruction and developments in Russia, China, and elsewhere are also of concern to the United States and its allies.

PUBLICATIONS:

Kamp, K.-H., and Yost, D. (Eds.), *NATO and 21st Century Deterrence, Forum Paper No. 8*, Rome: NATO Defense College, May 2009 (http://www.ndc.nato.int/download/publications/fp_08.pdf).

Yost, D., "Assurance and U.S. Extended Deterrence in NATO," *International Affairs*, Vol. 85, No. 4, pp. 755-780, July 2009.

NATIONAL SECURITY AFFAIRS

Yost, D., "Introduction to the Special Issue on NATO and Deterrence," *Strategic Insights*, Vol. 8, No. 4, September 2009
(<http://www.nps.edu/Academics/centers/ccc/publications/OnlineJournal/2009/Sep/introSep09.html>).

Yost, D., "NATO's Deterrence Challenges: Report on a Workshop in Vilnius, Lithuania, 10-12 May 2009," *Strategic Insights*, Vol. 8, No. 4, September 2009
(<http://www.nps.edu/Academics/centers/ccc/publications/OnlineJournal/2009/Sep/workshopSep09.html>).

Yost, D., "NATO and Tailored Deterrence: Key Workshop Findings in 2007-2008," *Strategic Insights*, Vol. 8, No. 4, September 2009
(<http://www.nps.edu/Academics/centers/ccc/publications/OnlineJournal/2009/Sep/yostSep09.html>).

Yost, D., "NATO and Tailored Deterrence: Surveying the Challenges," *NATO and 21st Century Deterrence, Forum Paper No. 8*, K.-H. Kamp and D. Yost (Eds.), Rome: NATO Defense College, pp. 11-31, May 2009 (http://www.ndc.nato.int/download/publications/fp_08.pdf).

PRESENTATIONS:

Yost, D., "Integrating the Findings: Reconciling Deterrence Requirements and Arms Control Priorities," NATO's Deterrence Challenges, Vilnius, Lithuania, 12 May 2009.

Yost, D., "NATO's New Allies and Extended Deterrence," Extended Deterrence and Assurance in the Emerging Global Security Environment, Institute for Defense Analyses, Alexandria, Virginia, 6 February 2009.

Yost, D., "U.S. Extended Deterrence in the Current Context," The Future of Extended Deterrence, Fondation pour la Recherche Stratégique, Paris, France, 16 November 2009.

NATO AND TAILORED DETERRENCE, PHASE I

David S. Yost, Professor
Department of National Security Affairs
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To gain a better understanding of Allied views on deterrence policy issues and to examine the relevance for the Alliance of the concept of "tailored deterrence" in particular. This research will investigate what the United States and its NATO Allies can do to improve the Alliance's deterrence posture and adjust it to the requirements of specific contingencies involving particular adversaries.

**DEPARTMENT OF
NATIONAL SECURITY AFFAIRS**

**2009
Faculty Publications
and Presentations**

NATIONAL SECURITY AFFAIRS

PUBLICATIONS

Kamp, K.-H., and Yost, D. (Eds.), *NATO and 21st Century Deterrence, Forum Paper No. 8*, Rome: NATO Defense College, May 2009 (http://www.ndc.nato.int/download/publications/fp_08.pdf).

Yost, D., "Assurance and U.S. Extended Deterrence in NATO," *International Affairs*, Vol. 85, No. 4, pp. 755-780, July 2009.

Yost, D., "Introduction to the Special Issue on NATO and Deterrence," *Strategic Insights*, Vol. 8, No. 4, September 2009
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Yost, D., "NATO's Deterrence Challenges: Report on a Workshop in Vilnius, Lithuania, 10-12 May 2009," *Strategic Insights*, Vol. 8, No. 4, September 2009
(<http://www.nps.edu/Academics/centers/ccc/publications/OnlineJournal/2009/Sep/workshopSep09.html>).

Yost, D., "NATO and Tailored Deterrence: Key Workshop Findings in 2007-2008," *Strategic Insights*, Vol. 8, No. 4, September 2009
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Yost, D., "NATO and Tailored Deterrence: Surveying the Challenges," *NATO and 21st Century Deterrence, Forum Paper No. 8*, K.-H. Kamp and D. Yost (Eds.), Rome: NATO Defense College, pp. 11-31, May 2009 (http://www.ndc.nato.int/download/publications/fp_08.pdf).

PRESENTATIONS

Yost, D., "Collective Defense and Crisis Response as NATO Missions: Striking the Right Balance," NATO at 60: A Post-Summit Appraisal and a Look into the Next 20 Years, Dogus University, Istanbul, Turkey, 15 May 2009.

Yost, D., "Integrating the Findings: Reconciling Deterrence Requirements and Arms Control Priorities," NATO's Deterrence Challenges, Vilnius, Lithuania, 12 May 2009.

Yost, D., "NATO's Evolving Purposes," NATO's New Strategic Concept, Netherlands Atlantic Association and Atlantic Treaty Association, The Hague, Netherlands, 27 May 2009.

Yost, D., "NATO's New Allies and Extended Deterrence," Extended Deterrence and Assurance in the Emerging Global Security Environment, Institute for Defense Analyses, Alexandria, Virginia, 6 February 2009.

Yost, D., "U.S. Extended Deterrence in the Current Context," The Future of Extended Deterrence, Fondation pour la Recherche Stratégique, Paris, France, 16 November 2009.

CONTRIBUTIONS TO BOOKS

Yost, D., "NATO's Evolving Purposes and the Next Strategic Concept," *NATO's New Strategic Concept: Moving Beyond the Status Quo?*, B. Boxhoorn and D. den Dunnen (Eds.), pp. 30-53, The Hague: Netherlands Atlantic Association, 2009.

Yost, D., "Transforming NATO's Institutions," *A Compass for Peace: NATO's 60th Anniversary*, P. Beaver and G. McDonald (Eds.), pp. 56-59, London: Platinum, 2009.

**GRADUATE SCHOOL OF
OPERATIONAL AND
INFORMATION SCIENCES**

**PETER PURDUE
DEAN**

**DEPARTMENT OF
COMPUTER SCIENCE**

**PETER J. DENNING
CHAIRMAN**

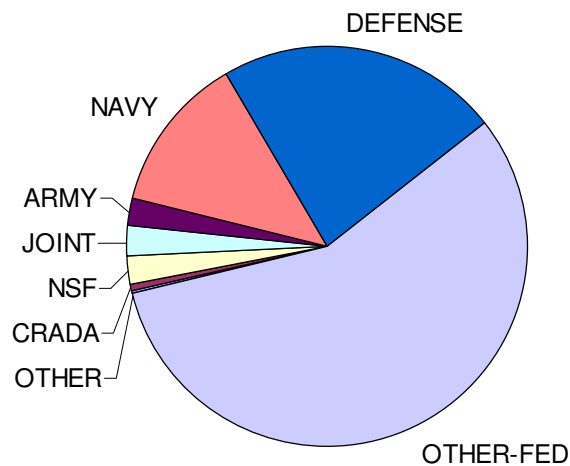
COMPUTER SCIENCE

OVERVIEW:

The Department of Computer Science provides graduate training and education in major areas of computer science. Both basic and advanced graduate courses are offered. Course work and research lead to either the degree of Master of Science, Doctor of Philosophy, or Master of Computing Technology. The requirements to complete any program are rigorous and comparable to those of other major universities.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Computer Science is provided below:



Size of Program: \$6M

COMPUTER SCIENCE

Peter J. Denning
Professor and Chair
Director of the Cebrowski Institute
831-656-3603
pjd@nps.edu

Mikhail Auguston
Associate Professor
831-656-2607
maugusto@nps.edu

Valdis A. Berzins
Professor
831-656-2610
berzins@nps.edu

Robert Beverly
Assistant Professor
831-656-2132
rbeverly@nps.edu

Karen Burke
Research Associate Professor
831-656-3988
klburke@nps.edu

Paul C. Clark
Research Associate
831-656-2395
pcclark@nps.edu

Richard S. Coté
Senior Lecturer
831-656-2519
rscoate@nps.edu

Christian J. Darken
Associate Professor
831-656-2095
cjdarken@nps.edu

Rudolph P. Darken
Professor
831-656-7588
darken@nps.edu

Arijit Das
Research Associate
831-656-3970
adas@nps.edu

Duane Davis
CDR, USN
Computer Science/MOVES/
Software Engineering
Program Officer
831-656-7980
dtdavi1@nps.edu

George Dinolt
Associate Professor
831-656-3889
gwdinolt@nps.edu

Doron Drusinsky
Associate Professor
831-656-2168
ddrusins@nps.edu

Chris Eagle
Senior Lecturer and
Associate Chair
831-656-2378
cseagle@nps.edu

John S. Falby
Senior Lecturer
831-656-3390
falby@nps.edu

John D. Fulp
Senior Lecturer
CISSP-ISSEP
831-656-2280
jdfulp@nps.edu

Simson Garfinkel
Associate Professor
831-656-7602
slgarfin@nps.edu

John Gibson
Lecturer
831-656-2902
jhgibson@nps.edu

John Hiles
Research Professor
831-656-2988
jehiles@nps.edu

Ted Huffmire
Assistant Professor
831-656-7601
tdhuffmir@nps.edu

Cynthia E. Irvine
Professor
831-656-2461
irvine@nps.edu

Matthew Kolb
LT, USN, Military Faculty
831-656-7980
mvkolb@nps.edu

Mathias N. Kolsch
Assistant Professor
831-656-3402
kolsch@nps.edu

Timothy E. Levin
Research Associate Professor
831-656-2239
levin@nps.edu

Theodore G. Lewis
Professor
831-656-2830
tlewis@nps.edu

Gilbert M. Lundy
Associate Professor
831-656-2094
blundy@nps.edu

Luqi
Professor
831-656-2735
luqi@nps.edu

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Craig H. Martell
Associate Professor
831-656-2110
cmartell@nps.edu

Robert B. McGhee
Professor Emeritus
831-656-2026
mcghee@nps.edu

James Bret Michael
Professor
831-656-2655
bmichael@nps.edu

William Murray
Visiting Professor
831-656-2830
whmurray@nps.edu

Thuy D. Nguyen
Research Associate
831-656-3989
tdnguyen@nps.edu

Thomas W. Otani
Associate Professor
831-656-3391
twotani@nps.edu

Loren Peitso
Senior Lecturer
831-656-3009
lepeitso@nps.edu

Richard Riehle
Visiting Professor
831-656-3316
rdriehle@nps.edu

Neil C. Rowe
Professor
831-656-2462
ncrowe@nps.edu

Alan B. Shaffer
CDR, USN, Military Faculty
Assistant Professor (PMP)
831-656-3319
abshaffe@nps.edu

David Shifflett
Research Associate
831-656-2652
shifflett@nps.edu

Man-Tak Shing
Associate Professor
831-656-2634
shing@nps.edu

Gurminder Singh
Professor
831-656-3041
gsingh@nps.edu

Joseph A. Sullivan
CDR, USN, Military Faculty
831-656-7582
jasullivan@nps.edu

Dennis M. Volpano
Associate Professor
831-656-3091
volpano@nps.edu

Daniel F. Warren
Senior Lecturer
831-656-2353
dwarren@nps.edu

Geoffrey G. Xie
Professor
831-656-2693
xie@nps.edu

Joel D. Young
Lt Col, USAF
Military Faculty
831-656-3518
jdyoung@nps.edu

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SEMANTIC ENTAILMENT DETECTION FOR CROSS-DOMAIN CHAT GUARDS

LT Paige Adams, USN

Department of Computer Science

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To demonstrate how U.S. participants can use a single workstation for multilevel access to U.S. and coalition WANs at different classification levels. In this ongoing project, current research is being conducted to explore the design and development of mechanisms that support emerging concepts for the Global Information Grid and network-centric warfare. In addition, this research is investigating extension of the number and type of applications supported by the testbed. This proposal is to further design and develop prototype, high-assurance services to meet the multilevel requirements of military and intelligence operations.

TESTING AUTOMATION TOOLS FOR MODELING AND SIMULATION SUPPORT

Mikhail Auguston, Associate Professor

Department of Computer Science

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To develop the methodology and framework for specifying environment models for ISNS for testing automation and modeling and simulation support.

TESTING AUTOMATION TOOLS FOR RAPID PROTOTYPING AND INTEGRATION OF ROBOTIC SYSTEMS

Mikhail Auguston, Associate Professor

Department of Computer Science

Sponsor: U.S. Army RDECOM TARDEC

SUMMARY: Researchers suggest an original approach to automatic scenario generation from environment models for testing of real-time reactive systems.

A COMMON SOFTWARE ARCHITECTURE FOR GROUND-BASED MILITARY-VEHICLE SYSTEMS

Valdis Berzins, Professor

Department of Computer Science

Sponsor: U.S. Army Tank Automotive Research, Development Engineering Center

OBJECTIVE: To define a common software architecture/product line for ground-based military-vehicle systems. To improve development, the right technology mix is needed in the areas of common software (embedded with common architecture), vehicle electronics (VETRONICS), and data-bus capability. Researchers will focus on methods for establishing real-time requirements for SoS COE, operating system and hardware, investigation into the best hardware solution for real-time control and the appropriate protocol for real-time control, and estimates of key results.

REDUCING TESTING COSTS FOR REUSABLE COMPONENTS IN OPEN ARCHITECTURES

Valdis Berzins, Professor

Department of Computer Science

Sponsor: Naval Sea Systems Command

SUMMARY: The Navy's open architecture framework is intended to promote reuse and reduce costs. However, current approaches to software acquisition require that reusable software components be retested each time they are used in a new context, which is a major contributor to cost per instance of reuse. This research focuses on exploiting open architectures principles to safely reduce testing costs for reusable

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software components. Software components that are reused without modification need to be retested in some (though not necessarily all) cases. This project will investigate conditions under which testing of unmodified components can be safely avoided, methods for identifying situations in which retesting can be safely reduced, and policies on how to effectively focus retesting in cases where some retesting is needed.

THE NAVY CERTIFIER PROGRAM, PHASE VII

Karen Burke, Research Associate Professor

Department of Computer Science

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To increase the capability of the Navy's Information Assurance Program in the area of system certification. It is subdivided into three tasks: 1) update the course materials, deliver to the Navy for printing prior to instructing the course, and shipping the materials; 2) teach the course in Charleston, South Carolina; and 3) evolve the material to synchronize with the latest Department of Defense Information Assurance Certification and Accreditation Process (DIACAP) and the Navy's process for certification and recommendation for accreditation. This special offering furthers the Navy Certifiers Education Program.

THE CELL BROADBAND ENGINE PROCESSOR ARCHITECTURE

George Dinolt, Associate Professor

Department of Computer Science

Sponsor: National Security Agency

OBJECTIVE: To illustrate how to use commercial, off-the-shelf, multi-core processors to achieve high-speed encryption in a fail-safe way. This research proposal documents follow-on work to a previous contract funded by the Air Force Crypto Modernization Office. The goal of this research is to extend the work previously done to investigate how the hardware-enforced security properties of the Cell Broadband Engine can be used to support both key agility and, along with the parallel processing properties of the Cell, provide additional fail-safe protections.

CELL BE RISK-REDUCTION ANALYSIS

George Dinolt, Associate Professor

Department of Computer Science

Sponsor: National Security Agency

OBJECTIVE: To design, implement, optimize, and characterize the AES encryption algorithm on single and multiple cores of the power PC Cell BE processing family.

DEVELOPMENT OF A FORMAL METHOD STRATEGY FOR THE NEXT-GENERATION SECURITY NETWORK SERVER

George Dinolt, Associate Professor

Department of Computer Science

Sponsor: Boeing Company

SUMMARY: Boeing is a leader in providing highly secure network solutions and information assurance. The SNS-4000 series is Boeing's next-generation, high-assurance, Multilevel Secure (MLS) guard based on field-programmable gate array (FPGA) components. The Naval Postgraduate School (NPS) and Boeing will collaborate to develop a formal methods strategy for the new SNS-4000 series, including generating the model for the entire system. Additionally, the components will be tested and evaluated for Common Criteria Evaluation Assurance Level 7.

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SOFTWARE CRYPTO MODELING

George Dinolt, Associate Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: To evaluate mathematical modeling techniques that could be used to support the detecting and handling of failures in software intensive encryption/decryption units. The failures identified would come from a formal model of the hardware and potential hardware.

SOFTWARE CRYPTO MODELING

George Dinolt, Associate Professor
Department of Computer Science
Sponsor: National Security Agency

SUMMARY: Most encryption units of highly sensitive intelligence data are implemented using significant amounts of hardware. Through long experience, the failure modes of such systems are well understood. Mechanisms that are protecting the sensitive information contained in these systems from failure are well understood. The equivalent mechanisms for software-based encryption systems are not known. The goal of this research is to apply newly discovered modeling techniques to try various hardware failure modes and protections mechanisms.

FORMAL UML REQUIREMENT SPECIFICATION-BASED AUTOMATIC SOFTWARE TESTING

Doron Drusinsky, Associate Professor
Department of Computer Science
Sponsor: U.S. Marine Corps Systems Command

OBJECTIVE: To assist and guide the National Aeronautics and Space Administration Independent Verification and Validation (NASA IV&V) Center in UML-based specification, modeling, programming, code-generation, validation, testing, and verification of safety critical systems and distributed systems.

FORMAL UML REQUIREMENT SPECIFICATION-BASED AUTOMATIC SOFTWARE TESTING

Doron Drusinsky, Associate Professor
Department of Computer Science
Sponsor: U.S. Marine Corps Systems Command

OBJECTIVE: To provide a proof-of-concept for using requirement/assertion-based automatic test-generation for the purpose of secure COC software validation. The suggested novel innovation is in the use of automated monitors, based on UML-based formal assertions.

UML-BASED VALIDATION AND VERIFICATION

Doron Drusinsky, Associate Professor
Department of Computer Science
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: To assist and guide the National Aeronautics and Space Administration Independent Verification and Validation (NASA IV&V) Center in UML-based specification modeling, programming, code-generation, validation, testing, and verification of safety critical systems and distributed systems.

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FIELD-DEPLOYABLE DIGITAL DATA ACQUISITION UTILITIES

Chris Eagle, Senior Lecturer
Department of Computer Science
Sponsor: Washington Security Group

SUMMARY: The collaborators agree to perform the following tasks:

The Naval Postgraduate School (NPS) will be responsible for the following tasks:

1. Design and develop the Microsoft Outlook analysis engine.
2. Develop and incorporate the dictionary-oriented data-extraction engine into the digital data-acquisition equipment.
3. Design and integrate the anti-reverse engineering features into the kit.
4. Develop a software user's manual.

The Washington Security Group, Inc. (WSG) will be responsible for the following tasks:

1. Develop and deliver test articles for the email analysis engine.
2. Generate test articles for the dictionary-oriented extraction engine.
3. Test and evaluate the integrated components.
4. Produce filed deployment package.

NPS and WSG will be responsible for the following joint tasks:

1. Test, analyze, evaluate, and refine the analysis and dictionary-oriented extraction engines.
2. Identify and coordinate areas of improvement and provide recommendations.

SECURITY ANALYSIS OF THE INTEL EXTENSIBLE FIREWARE INTERFACE BIOS

Chris Eagle, Senior Lecturer
Department of Computer Science
Sponsor: Naval Information Operations Command-Suitland

OBJECTIVE: To investigate the strengths and weaknesses of the new EFI BIOS standard from Intel from a computer security standpoint.

SECURITY ANALYSIS OF SOFTWARE TAMPER-PROTECTION MECHANISMS

Chris Eagle, Senior Lecturer
Department of Computer Science
Sponsor: Air Force Research Laboratory

OBJECTIVE: To attempt to demonstrate techniques and develop tools for defeating anti-tamper mechanisms in sponsor-provided software programs. A measure-of-effectiveness of each anti-tamper protocol will be generated that summarizes the skills and experience level required to bypass each protection mechanism. The principal investigators will provide quarterly reports to the sponsor.

AUTOMATED MEDIA EXPLOITATION AND INFORMATION FUSION

Simson L. Garfinkel, Associate Professor
Department of Computer Science
Sponsor: Marine Corps Systems Command

OBJECTIVE: To create breakthrough algorithms and information management approaches that will enable a new generation of automatic, battlefield forensic-analysis tools. Such tools are largely absent today because of the lack of principled techniques for the automated handling of forensic datasets and the lack of attention to usability on the part of current tool developers.

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AUTOMATED MEDIA EXPLOITATION RESEARCH FY10

Simson L. Garfinkel, Associate Professor

Department of Computer Science

Sponsor: Defense Intelligence Agency

OBJECTIVE: The Naval Postgraduate School will provide research and development to assist automated media exploitation.

THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY COMPUTER FORENSIC TOOL TESTING PROGRAM SUPPORT

Simson L. Garfinkel, Associate Professor

Department of Computer Science

Sponsor: National Institute of Standards and Technology

OBJECTIVE: The Naval Postgraduate School will assist the National Institute of Standards and Technology Computer Forensic Tool Testing Program by developing UNIX source code and hosting a workshop on automated media exploitation.

SECTOR DISCRIMINATION SEEDLING

Simson L. Garfinkel, Associate Professor

Department of Computer Science

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: To develop and test a principled approach for identifying individual disk sectors. Some sectors (such as the sector of all NULs) commonly occur in many files; other sectors (such as sector encrypted data) are “unique” – probabilistically, they will never occur elsewhere on the planet unless a bit-for-bit copy of that sector is made. Still other sectors (like a sector from a Wikipedia article) may be unique in themselves, but may contain internal structures that allow them to be identified with a high degree of accuracy. This project would attack the sector discrimination problem with three different approaches, build a prototype sector discrimination engine, and test that engine with two datasets. The testable hypothesis is that the speed, accuracy, and coverage of sector discrimination can dramatically improved from the current method, which relies on the identification of file headers and unique hashes from the NSRL dataset.

This project will use Defense Advanced Research Projects Agency (DARPA) funds for computing sector hashes for all of the NIST NSRL, improving the Bloom Filter technology that the principal investigator has been working on, and exploring a new algorithm that Vassil Roussev at Tulane has developed for identifying high-entropy features on the sub-sector level.

DESIGNING SECURE MULTI-CORE SYSTEMS ON RECONFIGURABLE HARDWARE

Theodore Huffmire, Assistant Professor

Department of Computer Science

Sponsor: Naval Postgraduate School

OBJECTIVE: To develop design techniques to enhance the security of chip-multiprocessor systems; and to evaluate these strategies on reconfigurable devices across a variety of classes of designs.

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AN ANALYSIS OF THE INFORMATION ASSURANCE IMPACT OF SELECTED EMERGING TECHNOLOGIES: PLANNING

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: To establish a framework for a set of activities to be conducted to investigate the information assurance impacts of emerging technologies on behalf of the National Security Agency. The work will entail the development of a detailed plan for technology studies and will use a set of selected analyses as pilot analyses to validate the results.

THE HIGH ASSURANCE PLATFORM: CORE PLATFORM AND SECURITY CRITERIA REQUIREMENTS ELICITATION AND ANALYSIS

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: The National Security Agency (NSA) High Assurance Platform (HAP) Program is a government-sponsored, longitudinal effort to develop a set of high-confidence computing components for use in a range of operational contexts. This proposal describes research to conduct analysis, reviews, and create reports and documentation that can be incorporated into the computing platform architecture and security criteria (CPASC) specification for the HAP program.

THE HIGH ASSURANCE PLATFORM: HAPR2-C SECURITY REQUIREMENTS THE HIGH ASSURANCE PLATFORM – HAPR2-C SECURITY REQUIREMENTS DEFINITION

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: The National Security Agency (NSA) High Assurance Platform (HAP) Program is an effort to define a framework for the development of high-confidence computing components for use in a range of operational contexts. To help validate the applicability of emerging hardware and software technologies, and the effective use of the target computing platform in different operational use-scenarios, the HAP Program also develops interim HAP reference implementations. The HAP Release 2 (HAPR2) implementation is ongoing. The goal of this effort is to develop a set of commercially achievable security requirements for the HAPR2 implementation that can be incorporated into the computing platform architecture and security criteria (CPC) specification for the HAP Program. This investigation will also include a preliminary study of a composition of assumable platform instances from HAP-conformant platforms.

MONARCH: CYBER CORPS THROUGH METAMORPHOSIS

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: To reduce the current personnel gap in cyber security for the national information infrastructure. The project is unique in that it will not only provide Master's-level education to traditionally educated, computer-science graduates, but will also demonstrate that individuals with aptitude can make the leap to computer science and information assurance through a transformative Master's degree program and join a cadre of professionals able to address the cyber security challenges of the nation.

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MYSEA, PHASE VI
Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: National Reconnaissance Office

OBJECTIVE: In the Department of Defense (DoD) and the intelligence community, access to information at different sensitivity levels is a critical capability, yet there is a lack of highly secure, multi-level systems. Current needs point toward solutions able to adapt to changing situations and threats that must also be affordable, usable, and highly effective. MYSEA Phase VI will develop field-ready capabilities for multilevel, adaptive information and security services, which will demonstrate the feasibility of the MYSEA distributed architecture. Affordability is based on the judicious, minimized use of high-assurance (expensive) components; usability is supported via common commercial products and their interfaces; and the high-assurance evaluation target reflects the comprehensive effectiveness of this solution. MYSEA Phase VI is comprised of several research areas: distributed, multi-level security services; support for adaptive security; scalability analysis and testing; infrastructure support; and evaluation/accreditation support. It extends the existing MYSEA prototype and will be developed, tested, and measured in the controlled MLS testbed environment.

RESEARCH ASSISTANT INTERNSHIPS WITH THE DEFENSE MANPOWER DATA CENTER – SUMMER 2009

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: Defense Manpower Data Center

OBJECTIVE: To establish a symbiotic relationship between the Defense Manpower Data Center (DMDC) and the Naval Postgraduate School's Scholarship for Service (SFS) program that is coordinated by the Center for Information Systems Security Studies and Research (CISR). The SFS students that elect to intern with the DMDC will assist the DMDC in various project aspects pertaining to computer security and information assurance.

TEAM MONTEREY: AN ANALYSIS OF IDENTITY MANAGEMENT SECURITY FOR GROUPS

Cynthia E. Irvine, Professor
Department of Computer Science
Sponsor: Defense Manpower Data Center

SUMMARY: The Department of Defense maintains approximately 15,000 networks incorporating on the order of 7 million computers that are attacked approximately 50,000 times per day. Among these assets are databases containing high value information, which must be protected from adversarial exploits. Standard best practices in system security management provide considerable protection, yet for high-value information, many risks are unknown. The objective of the proposed work is to conduct analyses of risks associated with large datasets. The analyses will include examination of techniques that would permit unauthorized access to data; methods to extract high-value data; identification and parameterization of metadata in support of data extraction; identification of issues associated with multi-domain use of data; and estimation of exposure costs for selected sets of high-value information.

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EVALUATION AND INTEGRATION OF VIDEO/TRACKING TECHNOLOGY IN RAPID DEPLOYMENT SITUATIONS

Mathias N. Kolsch, Assistant Professor
Department of Computer Science
Sponsor: Kestrel Technologies, L.L.C.

SUMMARY: The Naval Postgraduate School (NPS) and Kestrel will be responsible for the following joint tasks: 1) capture video from a live stream; 2) input video metadata (telemetry) which will enable remote measurement and transferring of information to the operators; 3) conduct the temporal synchronization of video metadata to video; 4) replay video and metadata storage; and 5) display of aerial video in RAPIDS as a perspective overlay over the terrain in question.

ASSESSING THE RISK OF COMMERCIAL, OFF-THE-SHELF SOFTWARE FOR OPEN-ARCHITECTURE-BASED U.S. NAVY WEAPON-SYSTEM ACQUISITION PROGRAMS

Luqi, Professor
Department of Computer Science
Sponsor: Naval Special Warfare Command

SUMMARY: New weapon systems acquired by the Department of Defense are based on the idea of Open Architecture (OA) which is a business and technical strategy for acquiring and maintaining interoperable systems. One of the main risks associated with implementing OA successfully is the management of risk associated with commercial, off-the-shelf (COTS) software. Using COTS software has many benefits, including a reduced development cost, reduced integration timelines, and reduced impact to the customer during the initial integration phase. COTS software risks relative to Naval weapon software acquisition include actual software effectiveness, lack of subject matter experts (SM Es) on the acquisition team, increased vulnerability during integration with other systems, difficulty obtaining Weapon System Explosive Safety Review Board (WSESRB) concurrence on a design that is not fully understood by the acquisition team, and configuration management supportability resulting in potential cost and schedule overrun and safety problems. The goal of this research is to study the properties of a COTS-based integration in order to determine if a data model exists to support a risk mitigation strategy. The data being used to for this research is from the Defense Acquisition Management Information Retrieval (DAMIR) system and case studies on select OA-based weapon systems.

AUTONOMIC SYSTEM ADAPTATION TO DYNAMIC ENVIRONMENTS: ROBUSTNESS AND SELF-HEALING

Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: Workshop participants will explore a variety of theories and case studies to assess the strengths and weaknesses of different approaches to adaptive digital systems that can provide robust, dependable service even during disruptions and have the ability to recover from failures and attacks. The workshop will evaluate the effectiveness of biologically inspired and other techniques for the architecting, development, and autonomous operations of complex digital systems.

DOCUMENTATION-DRIVEN SOFTWARE DEVELOPMENT

Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: To develop an integrated, systematic, documentation-centric approach to software development, known as documentation driven development (DDD) approach.

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ESTABLISH/MAINTAIN A SOFTWARE ENGINEERING TEST LAB

Luqi, Professor

Department of Computer Science

Sponsor: Joint Information Operations Center

OBJECTIVE: To establish a lab for the purpose of stress testing real Department of Defense (DoD) systems with an emphasis on a holistic approach. The systems will be made available through a separate internet service provider (ISP) than the Naval Postgraduate School's (NPS) to enable the testing of different access configurations and to allow for outside entities to red team the systems. This lab will be used to evaluate multiple different DoD systems over the years. Four full-time NPS students will work in the lab over the next four years. The Naval Postgraduate School will install systems selected by IIOC in the SETL. NPS will install test hardware/software; maintain the systems; evaluate systems capability and usability in different deployment paradigms; evaluate security and safety vulnerabilities; and provide a lab space, lab management, and network connectivity.

THE RISK ASSESSMENT IN SOFTWARE PROJECT

Luqi, Professor

Department of Computer Science

Sponsor: Naval Air Warfare Center-Weapons Division

OBJECTIVE: To develop a set of quantitative metrics for four indicators of risk in an evolutionary software project. These metrics can be automatically collected early in each cycle in the evolutionary development of a software project. They will be the basis for building a formal risk assessment model that will make different program managers derive the same projections on the same software project.

TOOLS FOR TOPIC ANALYSIS IN BLOGS AND ONLINE CHAT

Craig H. Martell, Associate Professor

Department of Computer Science

Sponsor: National Reconnaissance Office

OBJECTIVE: Computer-mediated communication methods, such as e-mail, weblogs, chat, and instant messaging, have become important tools in modern society. For many uses, they have supplanted more traditional forms of communication, such as written letters, facsimiles, and telephone conversations. The proliferation of these tools has resulted in the accumulation of large amounts of data that might contain useful, actionable information. However, due to the dynamic nature of the media and the unstructured flow of conversation – especially in weblog comments, chat, and instant messaging – it is difficult to extract the meaning of a communication. Although much work has been done in the realm of e-mail and document topic detection – motivated in no small part by the desire to detect and filter spam and phishing – chat and instant-messaging topic detection remain a challenge. In this research, techniques for retrieving topics of interest from chat and instant messaging conversations will be explored.

THE DEVELOPMENT OF A REFERENCE MODEL IN SUPPORT OF VERIFICATION AND VALIDATION OF SYSTEMS

James Bret Michael, Professor

Department of Computer Science

Sponsor: National Aeronautics and Space Administration

OBJECTIVE: To assist the NASA Independent Verification and Validation Facility in establishing a system reference model to be used to specify the desired behavior of systems, under both nominal and degraded modes of operation, in support of system validation and verification.

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DESIGNING A CONCEPTUAL DATA MODEL FOR THE ACSIS DATABASE

**Thomas W. Otani, Associate Professor
Department of Computer Science**

Sponsor: Program Executive Office Command Control Communications-Tactical

OBJECTIVE: The Army C4ISR and Simulation Initialization System (AC SIS) database is comprised of various data tiles, collectively supporting the Army's Operational Battle Command and its training requirements. To facilitate a consistent and integrated software-development process for the data products that utilize the ACSIS database, it is indispensable to provide a high-level conceptual data model of the ACSIS database. A well-designed conceptual data model will provide clear and semantically rich information on the data and their relationships stored in the database. With such a conceptual data model for the ACSIS database, developers cannot be expected to construct the data products correctly and effectively. The objective of this applied research is to analyze the data requirements of the ACSIS database and produce a conceptual data model for it.

EXP-SA: ADAPTIVE-AUTOMATED DETECTION OF EMPLACEMENT OF EXPLOSIVE DEVICES

**Neil C. Rowe, Professor
Department of Computer Science
Sponsor: National Science Foundation**

OBJECTIVE: To focus on the most solvable problem in thwarting improvised explosive devices, namely, detection of their emplacement.

JOINT MOBILE NETWORK OPERATIONS JOINT TEST AND EVALUATION

**Gurminder Singh, Professor
Department of Computer Science
Sponsor: Joint Mobile Networks Operation**

SUMMARY: The Joint Mobile Network Operations Joint Test and Evaluation (JMNO JT&E) project is chartered to employ multi-service and other Department of Defense support, personnel, and equipment to investigate, evaluate, and make recommendations to improve mobile network and equipment to investigate, evaluate, and make recommendations to improve mobile network access and maintain current performance by identifying and developing joint doctrine and recommending DOTMLPF changes, and enhance user connectivity.

SENSOR ANALYSIS FOR THE CBP TUNNEL PROBLEM

**Gurminder Singh, Professor
Department of Computer Science
Sponsor: TRADOC Analysis Center-Monterey**

OBJECTIVE: To develop sensor data for urban sensor scenarios to compliment border sensor scenarios in an effort to determine sensor configuration to apply to defeat tunnels. The focus of the CBP project is to detect the digging of underground tunnels across the United States border.

SHARED TEXT INPUT

**Gurminder Singh, Professor
Department of Computer Science
Sponsor: Naval Postgraduate School Foundation, Inc.**

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VIRTUAL WORLD DNA: VIRTUAL WORLD DYNAMIC NETWORK ANALYSIS

Gurminder Singh, Professor

Department of Computer Science

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: In the last decade, social network analysis (SNA) tools have gained considerable interest in the intelligence and military communities as terrorist networks have become more global, decentralized, and flexible. Additionally, recent concerns have been voiced that social networking websites and virtual worlds provide likely breeding grounds for terrorist recruitment, communication, and coordination activities. This innovation project will research and develop the tools and techniques necessary for dynamic network analysis (DNA) of terrorist activities in virtual worlds, such as second life. Research will be conducted into applying network theoretic tools to understanding if and how terrorist networks can take advantage of virtual worlds, and furthermore, how strategies can be developed to disrupt these networks. First, techniques for personal and automated data mining for intelligence information will be investigated. Next, tools will be designed that are capable of graphically depicting network topological structures from such mined intelligence. Finally, dynamic network tools will be investigated and developed.

COLLABORATIVE RESEARCH – NBD: AN ABSTRACTION-DRIVEN APPROACH TO CHARACTERIZING AND DESIGNING NETWORKS WITH ANALYZABLE PROPERTIES

Geoffrey G. Xie, Professor

Department of Computer Science

Sponsor: National Science Foundation

OBJECTIVE: To investigate a new class of abstractions that are task driven; to capture the intended performance, security, manageability, or resilience of a network design; and, network wide, to capture the requirements of the network as a whole rather than of individual devices.

COLLABORATIVE RESEARCH – NETS-NBD: A REVOLUTIONARY 4D APPROACH TO NETWORK-WIDE CONTROL AND MANAGEMENT

Geoffrey G. Xie, Professor

Department of Computer Science

Sponsor: National Science Foundation

OBJECTIVE: To explore a number of fundamental questions related to network control and management. The focus of the research will be on IP (layer-3) networks, though the intent is to create networking primitives and servers that apply equally well to other technologies, such as layer-2 networks.

AN INVESTIGATION OF SELECTED INFORMATION ASSURANCE TOPICS

Geoffrey G. Xie, Professor

Department of Computer Science

Sponsor: National Security Agency

SUMMARY: Since October 2005, the principal investigator has led a group of Naval Postgraduate School faculty and students to address information assurance topics provided by the National Security Agency System and Network Analysis Center (SNAC) through reimbursable thesis research.

DEPARTMENT OF COMPUTER SCIENCE

**2009
Faculty Publications
and Presentations**

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**DEPARTMENT OF
DEFENSE ANALYSIS**

**GORDON H. MCCORMICK
CHAIRMAN**

DEFENSE ANALYSIS

OVERVIEW:

The Department of Defense Analysis is home to two unique, interdisciplinary graduate programs, drawing on a wide range of academic specialties. The program provides a focused course of instruction on the dynamics of irregular warfare/sub-state conflict, including terrorism, counter-insurgency, unconventional warfare, stability operations, information operations, and other “high leverage” operations in U.S. defense and foreign policy. The core program also provides every student with a strong background in strategic analysis, international relations and comparative politics, organization theory, and formal analytical methods. The Department’s mission is to prepare the Department of Defense’s future leadership with the critical thinking skills necessary to prepare for the complex operating environments of the 21st century.

CURRICULUM SERVED:

- U.S. Special Operations Forces
- Combating terrorism fellowship program-sponsored international officers
- DoD information operations professionals
- Select U.S. conventional forces officers

DEGREES GRANTED:

- Master of Science in Defense Analysis
- Master of Science in Joint Information Operations

RESEARCH THRUSTS:

- Special Operations
- Irregular Warfare (includes terrorism, counter-insurgency, and unconventional warfare)
- Information Operations
- Defense and Foreign Policy

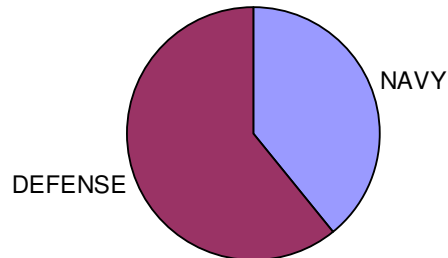
RESEARCH CENTERS:

- Center on Terrorism and Irregular Warfare
- Common Operational Research Environment (CORE) Lab
- Information Operations Center of Excellence Affiliate (one of three affiliates with the Department of Information Sciences and the Cebrowski Institute)

DEFENSE ANALYSIS

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Defense Analysis is provided below:



Size of Program: \$1.6M

DEFENSE ANALYSIS

Gordon H. McCormick
Chairman
831-656-2933
gmcormick@nps.edu

David Tucker
Associate Chairman,
Research
831-656-3754
detucker@nps.edu

Douglas A. Borer, Ph.D.
Associate Chair,
Instruction
831-656-2117
daborer@nps.edu

Brian Greenshields
Associate Chair,
Operations
831-656-3998
bhgreens@nps.edu

John Arquilla
Associate Professor
831-656-3450
jarquilla@nps.edu

William Fox
Professor
831-656-3753
wpfox@nps.edu

Glenn E. Robinson
Associate Professor
831-656-2710
grobinson@nps.edu

Leo Blanke
Professor
831-656-2933
ljblanke@nps.edu

Michael Freeman
Assistant Professor
831-656-3731
mefreema@nps.edu

Hy S. Rothstein
Senior Lecturer
831-656-2203
hsrothst@nps.edu

Douglas Borer
Associate Professor
831-656-2117
daborer@nps.edu

Frank Giordano
Professor
831-656-7500
frgiorda@nps.edu

Kalev Sepp
Assistant Professor
831-656-2116
kisepp@nps.edu

Nancy Ann Budden
Director, Special Operations
Technology
831-656-3332
nbudden@nps.edu

Heather Gregg
Professor
831-656-3689
hsgregg@nps.edu

Anna Simons
Associate Professor
831-656-1809
asimons@nps.edu

Dorothy Denning
Professor
831-656-3105
dedenning@nps.edu

Pete Gustaitis
Senior Lecturer and Associate
Chair for Operations
831-656-3799
pjgustai@nps.edu

Kristen Tsolis
Research Associate Professor
831-656-7604
ktsolis@nps.edu

Jennifer J. Duncan
Research Associate
831-656-3584
jduncan@nps.edu

George Lober
Senior Lecturer
831-656-1019
gwlober@nps.edu

Sean Everton
Professor
831-656-2023
sfeverto@nps.edu

Nancy Roberts
Professor
831-656-2742
nroberts@nps.edu

DEFENSE ANALYSIS

NETWORK WARFARE: WHAT'S NEXT? FY09 (U) INFORMATION OPERATIONS CENTER OF EXCELLENCE

John Arquilla, Associate Professor
Department of Defense Analysis
Sponsor: Office of the Secretary of Defense

SUMMARY: Objective and payoff networks themselves, the principal drivers of NETWAR, are relatively new organizational forms that are still not particularly well understood. Defeating them requires understanding them, mapping them, and learning how to target their various links and nodes. Like the tip of an iceberg, the visual components of networks may appear insignificant, but there is always plenty going on beneath the surface – both in friendly and hostile networks.

One obscure principal task is to learn to explore these nether regions better, as a deeper understanding of our networked foes and our own networking capabilities will likely be the key to developing an ability to influence network decision-makers and will greatly inform and enliven our own strategies.

THE THREE CIRCLES OF WAR IN IRAQ

John Arquilla, Associate Professor
Hy S. Rothstein, Senior Lecturer
Heather S. Gregg, Assistant Professor
Glenn E. Robinson, Associate Professor
Department of Defense Analysis
Sponsor: Office of the Secretary of Defense – Rapid Response and Technology Office

OBJECTIVE: To analyze identity politics in Iraq and how the 2003 conflict changed and was changed by the fluid nature of identity groups. Phase two of this project is to convert the research into book form, to be published by Potomac Books.

PUBLICATIONS:

Robinson, G.E., "Identity Politics and the War in Iraq," *The Three Circles of War: Understanding the Dynamics of Conflict in Iraq*, H.S. Gregg, H.S. Rothstein, and J. Arquilla (Eds.), Herndon, Virginia: Potomac Books, 2010.

Robinson, G.E., "Iraq's Insurgencies in Comparative Perspective," *The Internationalization of Domestic Conflict*, A.L. Freedman (Ed.), Toronto: University of Toronto Press, 2010.

KEYWORDS: Information Operations, Iraq, Tribes, Identity Politics

THE RATIONAL EMPIRE: AN INSTITUTIONAL THEORY OF IMPERIAL EXPANSION

Leo Blanken, Professor
Department of Defense Analysis
Sponsor: Naval Postgraduate School

OBJECTIVE: To complete revisions on a book-length manuscript.

THE CORE LAB MISSION AND DISTINCTIVE COMPETENCY

Douglas Borer, Associate Professor
Department of Defense Analysis
Sponsor: Office of the Secretary of Defense

SUMMARY: The CORE Laboratory was established in 2007 in order to support two curricula in the Defense Analysis Department: Special Operations (SO) and Information Operations (IO). The two curricula focus on special operations, intelligence, information operations, psychological operations, civil-

DEFENSE ANALYSIS

military operations, counter-insurgency, counter-terrorism, irregular and asymmetric warfare, and stability operations. There are actually two CORE Labs—an unclassified lab in Root Hall and a classified lab in Glasgow Hall—to accommodate a range of research interests and needs.

The CORE Lab focuses on the following three areas in support of irregular warfare: 1) the teaching of analytical methods (social network analysis, geo-spatial and temporal analysis) and the choice of software platforms to facilitate data fusion; 2) the testing and development of software and supporting technologies to improve information and knowledge management; and 3) the analysis of data to identify alternative strategies for field-based operations. In addition, it offers four quarter-long, lab-sponsored courses in the defense analysis curriculum (visual analytics, geospatial analytics, social network analysis, and dynamic social network analysis). Students also join faculty in conducting research, beta testing software and hardware, and providing command outreach/executive education.

THE CORE LAB PROGRAM – FY09
Douglas Borer, Associate Professor
Department of Defense Analysis
Sponsor: Office of the Secretary of Defense

OBJECTIVE: To establish a Common Research Environment (CORE) Program within the Center for Terrorism and Irregular Warfare (CTIW). The intent of this program is to leverage analytical technologies to educate the officer corps on how to apply theoretical concepts to the problems of terrorism and irregular warfare.

THE CORE LAB SOFTWARE REQUIREMENT
Douglas Borer, Associate Professor
Department of Defense Analysis
Sponsor: Office of the Under Secretary of Defense

OBJECTIVE: To obtain software and licenses from vendors in the areas of link analysis, geo-spatial analysis, and social network analysis.

DEFENSE COUNTER-TERRORISM TECHNOLOGY
Nancy Ann Budden, Director, Defense Counter Terrorism
Technology Office of the Secretary of Defense
Department of Defense Analysis
Sponsor: Office of the Secretary of Defense

OBJECTIVE: To promote and support the development, demonstration, and rapid transition of counter terrorism technologies in response to critical Department of Defense (DoD) requirements. The Naval Postgraduate School will provide a term civil service position to act as the Director for Defense Counter Terrorism Technology (DDCTT) under the Rapid Reaction Technology Office, DDR&E.

THE CORE LAB
Sean Everton, Assistant Professor
Department of Defense Analysis
Sponsor: Office of the Secretary of Defense

SUMMARY: In fall 2009, the principal investigator (PI) took over from Doug Borer as one of the co-directors of the CORE Lab, which functions as part of the Center for Terrorism and Irregular Warfare (CTIW) and the Department of Defense Analysis. The CORE Lab seeks to support field operatives engaged in irregular warfare through education, research, beta testing of hardware, and software and command outreach. While the CORE Lab is involved in several projects, the PI is actively involved in the following:

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- **Counter Terrorism Fellowship Program:** This project enables CORE to educate international students on the most recent academic methodologies and unclassified, analytical technologies available for gaining a broader and deeper understanding of the operational environment. Focused at the strategic and operational level, CORE Lab courses prepare international military officers and government officials to analyze the threats to their country and the resources they have available to combat those threats. Graduates will be able to serve as advisors to decision makers at all levels of the military and government on terrorism and insurgency, and to assist in the design of national, regional, service, and unit anti-terrorism and counter-insurgency plans.
- **FIST (Field Information Support Tool):** FIST is a hardware and software knowledge-management system that utilizes commercial, off-the-shelf and government, off-the-shelf equipment to enable the warfighter to collect, process, and analyze geospatial, temporal, and socio-cultural data. Although it is primarily focused on the development of three specific modules (Military Geography, Civil Affairs, and Tactical Conflict Assessment Planning Framework), the possibilities are essentially limitless with regards to data collection. The modules are easily created, highly configurable, and are managed via a centralized web service that allows for on-the-fly customization. Additionally, the server appliance that manages the collected data is equally as configurable and will allow for data collected to be routed to appropriate databases given access and specification.

FIST is designed to be scalable, customizable, flexible, and cost effective, while providing a technological advantage for the operator on the ground by automating and structuring information in such a way as to provide ubiquitous, interoperable information flow. A systems engineering approach was taken with regards to the design and implementation of the system architecture. Furthermore, the data obtained from FIST devices can be used to generate customized reports based on quantifiable, field-collected attributes. In conjunction with researchers in the CORE Lab, the FIST system looks to provide the front-end collection capability for link and social network analysis.

FIST is designed to be an application running on a smart phone that can be rapidly deployed to operators in the field in a matter of months and can integrate with existing systems currently fielded. The Military Geography module is one part of a larger overall effort to implement the usage of smart phones as data collection tools at the tactical, operational, and strategic levels of operation.

- **IW-Philippines Project:** Since 9/11, the United States has pursued two fundamentally distinct military approaches to combat terrorism and insurgencies: direct and indirect. Direct strategies are those that emphasize destruction of an enemy's capacity to fight by using kinetic means (the clash of arms) to "find, fix, and finish" the enemy's war-making machine (personnel, weapons, communications gear, supplies, etc.). Indirect approaches are those that emphasize the degrading of the enemy's will to fight by focusing on the material, cultural, and spiritual needs of the relevant population, a population which serves as the fundamental support element for terrorists and insurgents. In the battle against Philippine Islamist extremists (e.g., Jemaah Islamiyah, Abu Sayyaf Group, Raja Solaiman Group, Moro National Liberation Front, Moro Islamic Liberation Front), the government of the Philippines, strongly supported by the United States, has pursued a mix of both approaches. However, to a much greater extent, the emphasis has been on indirect methods rather than direct action. If judged in terms of outcomes, for the most part, the Philippines is a relative success story in the global war on terror. JI and ASG have been seriously degraded; most members of RSM have been captured or killed; and on Mindanao, the peace process between the government of the Philippines and the MNLF/MILF has moved forward. However, despite this relative success, this story has not been robustly studied by analysts from either a theoretical or an empirical perspective. This research proposes to do both.

The goal in this project is to identify and the various determinants (and non-determinants) of conflict and the conditions under which direct and indirect IW strategies are effective. Building upon previous research that collected and analyzed Philippine insurgency data from 2001-2004, this project analyzes an additional 26 years of data from the Philippines, affording researchers thirty years of temporal data (1978-2008). In addition, relational and geospatial data at the individual and insurgency level will enable the combining of various types of analytic approaches. In particular, such data will allow testing of alternative theories of irregular warfare through

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statistical analysis (e.g., pooled time series), empirical investigation (e.g., social network analysis), and comparative case studies.

STRATEGIC EXPLORATIONS: USING EXPLORATORY SOCIAL-NETWORK ANALYSIS TO DEVELOP STRATEGIES FOR TRACKING, DISRUPTING, AND DESTABILIZING DARK NETWORKS

Sean Everton, Research Associate professor
Department of Defense Analysis
Sponsor: Naval Postgraduate School

OBJECTIVE: To complete revisions on a book-length manuscript.

MODELING IRREGULAR WARFARE

William P. Fox, Professor
Mike Jaye, Associate Professor
Department of Defense Analysis
Jeffrey Appleget, Senior Lecturer
Department of Operations Research
Sponsor:

OBJECTIVE: To build a formal model or models for the three rings of the Iraq War.

THE RENAL CELL CASE STUDY FOR SURVIVABILITY

William P. Fox, Professor
Department of Defense Analysis
H. Thomas Temple, Department of Orthopedics
Dr. Andrea Evenski, Department of Orthopedics
University of Miami School of Medicine
Sponsor:

OBJECTIVE: To build a mathematical model for the survivability of patients with renal cancer.

SUMMARY: In survival analysis, researchers are interested in the time interval between entry into the study and an event. The outcome of interest is time to an event. Survival analysis was originally developed for studying time from commencement of treatment until death. This was commonly used for evaluating treatment efficacy in fatal conditions like cancer, hence the name. But survival analysis is applicable to many other situations in addition to mortality. For example, commencement of hormone replacement therapy and thrombotic episode; time to exercise to maximum tolerance; exclusive breast feeding and time to another pregnancy; time for leg fracture to heal; and so on. By convention, one mentions survival data and survival analysis in all such cases regardless of the nature of the event. In industry the same approach is used to test the reliability of appliances. Here the outcome of interest is time to breakdown. Hence, some computer packages (e.g., Minitab) refer to the procedure as reliability analysis.

The problem with studying the time between one event and another is twofold:

1. Time interval may vary from one subject to another. At the end of the follow-up period, the chances are that the event would probably not have happened for all the subjects. Therefore, time intervals are not expected to be distributed normally.
2. In studies requiring prolonged observation, some subjects are invariably lost to follow-up, and the only information available about them is that they were still alive at the time of the last follow-up. These are termed **censored observations**. Also, those subjects in whom the event has not occurred by the end of the follow-up period are considered censored. All studies last for a finite time. At the end, it is unknown when the remaining subjects will experience the event.

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In all survival studies, certain assumptions are made. Patients are recruited over a period and followed up to a fixed date beyond the end of recruitment. Some would stay in the study for a longer time than those who were recruited more recently. It is assumed that the survival prospects stay the same throughout the study.

It is also assumed that patients lost to follow-up have the same prognoses as those who continue in the study. A critical assumption is that the probability of an individual subject to be censored is unrelated to the probability of suffering the endpoint event.

From the study-design point of view, survival should always be evaluated in a cohort of patients followed forward in time from a particular start-point, such as randomization, even if the cohort is historical. The data is best looked at using the Kaplan-Meier Survival Curve.

PRESENTATIONS:

Fox, W., podium presentation, American Academy of Orthopaedic Surgery, New Orleans, Louisiana, March 2010.

Fox, W., poster presentation, International Society of Limb Salvage/Musculoskeletal Tumor Society, Boston, Massachusetts, 24 September 2009.

SENSING AND IDENTIFICATION OF PERSONS AND/OR ANIMALS WEARING WIRES FOR DETONATION

William P. Fox, Professor
Department of Defense Analysis
Sponsor: JIEDDO

OBJECTIVE: To build mathematical models to show the feasibility of detecting persons wearing wires for detonation.

SUMMARY: This Joint Improvised Explosive Device (IED) Defeat Organization research project executed by the Naval Postgraduate School and the University of California-Santa Cruz examined the ability to sense and identify people carrying wires on their body for IED detonation. Previous Army Research Laboratory (ARL) research on sensing people with weapons behind walls is instrumental in providing a framework for analysis.

The research effort began with background research into the problem, not from the standpoint of suicide bombing, but from the direction of using radars as a detection device for humans wearing wires. ARL research showed ways to use radar backscatter to detect humans with weapons behind walls.

The principal investigators (PIs) spent a lot of time developing NEC simulations for the human body and tested theory. The PIs used a GunnPlexer Doppler radar to collect experimental data from a standoff distance of approximately 50 meters so human subjects, human subjects wearing a wire loop, human subjects wearing a simulated vest with wire loops. The PIs performed numerous experiments and analyzed the data after each experimental run.

One purpose of this experimental data-collection analysis was to find metrics that could be used in building models to test detection rates. Several metrics that improved one's ability to detect persons wearing wires were found. The best metric was the VV/HH ratio of radar cross section. From empirical modeling, it was found that the ratio for people wearing wires was statistically different from people without wires at a level of significance $\alpha = 0.05$. Using that metric, a simulation model was built that generated a crowd of people and randomly picked those with wires on their person. A metric and a threshold value, determined experimentally, were used to distinguish the persons with wires from those without wires. The simulation picked the person with wires with a success rate of 0.834 or 83.4% based from running 1,000 trial runs 36 times. The rate of false alarms, the model picking people who were not wearing wires as suspects wearing wires, was about 0.22 or 22% of the time. It was also found that a frequency near 1 GHz radar cross section was a useful metric.

The report shows success in finding viable methods for detecting wires on people using radar observations. The preliminary research possible using the resources provided under this initial research and the exciting results it produced encourage proposed follow-on research in this important area.

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PUBLICATION:

Fox, W., Technical report for JIEDDO, EXCEL Model for JIEDDO, paper in draft form.

UNDERSTANDING DARK NETWORKS – THE NAVAL POSTGRADUATE SCHOOL/CTFP SECOND ANNUAL SYMPOSIUM

Brian Greenshields, Senior Lecturer

Department of Defense Analysis

Sponsor: Naval Education Training Security Assistance Field Activity

SUMMARY: The Naval Postgraduate School's Department of Defense Analysis proposes a three-day "Combating Terrorism Fellowship Program Alumni Symposium," from 16 -20 August 2009 in Garmisch, Germany. The academic purpose of the symposium is to re-engage CTFP alumni from the CENTCOM, EUCOM, and AFRICOM region in a dialogue on identifying, disrupting, and targeting transnational terrorist/criminal networks.

RELIGIOUSLY MOTIVATED VIOLENCE: WHERE DOES IT COME FROM? CAN IT BE DETERRED?

Heather S. Gregg, Assistant Professor

Department of Defense Analysis

Sponsor: Naval Postgraduate School

OBJECTIVE: This research considers the different ways in which religion fuels violent behavior, ranging from religious-based ethics for using force to "cosmic war," in which violence becomes a sacred duty in defense of the faith. This research will also investigate the effects of kinetic operations—especially two major wars—on an ideology that claims Islam is under attack, and it will consider ways to fight the global war on terrorism *and* de-legitimize Al Qaeda's ideology.

USING JOBS PROGRAMS TO DEFEAT IMPROVISED EXPLOSIVE DEVICE NETWORKS

Heather S. Gregg, Assistant Professor

Department of Defense Analysis

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To goal is to attack the networks that engage in insurgent activity and use IEDs by positively interacting with the populace and strengthening the pillars of stabilization—security, governance, an economic development—offering young men alternatives to insurgency. The employment manual is a means of weakening insurgent networks while strengthening the capabilities of the host nation to govern and provide for its citizens.

DEFENSE ANALYSIS INSURGENCY AND MANHUNTING PROJECTS (U)

Gordon H. McCormick, Professor

Department of Defense Analysis

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To build a dynamic model of insurgency that clearly defines the variables, parameters, and relationships that shape the outcome of insurgent competitions.

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SUPPORT FOR CORE LAB INTERNATIONAL STUDENTS AND COURSE DEVELOPMENT

Nancy Roberts, Professor

Douglas Borer, Associate Professor

Department of Defense Analysis

Sponsor: Counter Terrorism Fellowship Program

OBJECTIVE: To educate international students on the most recent academic methodologies and unclassified analytical technologies available for gaining a broader and deeper understanding of the operational environment. Focused at the strategic and operational level, CORE Lab courses prepare international military officers and government officials to analyze the threats to their country and the resources they have available to combat these threats. Graduates will be able to serve as advisors to decision makers at all levels of the military and government on terrorism and insurgency, and to assist in the design of national, regional, service, and unit anti-terrorism and counter-insurgency plans.

SUMMARY: This project is in two parts:

Part I: The CORE Lab sponsored the development of a new course entitled Visual Analytics. Visual Analytics addresses a common problem we all face—the collection of data at a faster rate than our ability to analyze it. The course’s general purpose is to introduce methods to examine and analyze massive, multi-dimensional, multi-source, time-varying data. It offers new tools and technology to integrate and fuse data to support the analytical process so we are better prepared to make decisions in a time-critical manner. The course’s specific goal is to teach students how to collect, manage, analyze, and fuse geospatial, temporal, and relational data in order to create a more complete understanding of insurgency and violent, extremist networks. Once the network data have been analyzed and fused, students then develop recommendations for higher authority on how to respond to the networks.

Part II: The CORE Lab also is collaborating with Dr. Chen of the University of Arizona’s Artificial Intelligence Laboratory. This aspect of the project (referred to as the Dark Web Forum) provides international students and alumni with the opportunity to: gain a broader understanding of how terrorist groups exploit web technologies in support of their campaigns; explore cutting-edge tools and methodologies for analyzing patterns about the recruitment, radicalization, and training activities of terrorist groups; investigate the use of emerging cyber technologies, social network analysis, and geospatial information systems for the purposes of tracking/disrupting terrorist networks; discover failures and best-practice approaches that terrorist groups use to support their propaganda, recruitment, fundraising, networking, and command and control activities; examine the evolving relationships between technologies and terrorist groups; determine options for detecting, monitoring, and analyzing the relationships between terrorist groups, as well as maximizing opportunities to exploit their weaknesses; and step back from day-to-day operations to enhance analytical skills in an emerging and critical specialty, “terrorism informatics” (the use of computational and web-based techniques in the study and analysis of terrorism-related activities).

Affiliated Researchers for Dark Web Forum:

- Dr. Chen, University of Arizona, Artificial Intelligence Lab, Co-Principal Investigator (PI)
- Dr. Nancy Roberts, Naval Postgraduate School (NPS), CORE Lab, Co-PI
- Dr. Dorothy Denning, NPS, Department of Defense Analysis
- Ms. Kristen Tsois, NPS, CORE Lab, Department of Defense Analysis
- Dr. John C. McEachen, NPS, Department of Electrical and Computer Engineering
- Dr. Murali Tummala, NPS, Department of Electrical and Computer Engineering
- Dr. Weilian Su, NPS, Department of Electrical and Computer Engineering

PUBLICATIONS:

Borer, D.A., Everton, S.F., and Nayve, M.M., “Global Development and Human (In)security: Understanding the Rise of the Rajah Solaiman Movement and Balik Islam in the Philippines,” *Third World Quarterly*, 30:181-204, 2009.

DEFENSE ANALYSIS

Maitre, B.R., "What Sustains 'Internal Wars'? The Dynamics of Violent Conflict and State Weakness in the Sudan," *Third World Quarterly*, 30(1): 181-204, 2009.

Roberts, N.C., "Entrepreneurship in Peace Operations," *Journal of Civic Society*, 2010 (in press).

Roberts, N.C., "Response to Commentaries of Spanning 'Bleeding Boundaries'," *Public Administration Review*, 2010 (in press).

Roberts, N.C., "Spanning 'Bleeding' Boundaries: Humanitarianism, NGOs, and the Civilian-Military Nexus in the Post-Cold War Era," *Public Administration Review*, 2010 (in press).

Roberts, N.C., "Tracking and Disrupting Dark Networks: Challenges of Data Collection and Analysis," *Information Systems Frontiers* (under review).

Roberts, N.C. and Everton, S., "Strategies for Combating Dark Networks," *Journal of Social Structure* (under revision).

PRESENTATIONS:

Borer, D.A. and Everton, S.F., "Global Development and the Rise of the Rajah Solaiman and Balik Islam Movements in the Philippines," Weatherhead East Asian Institute, Columbia University, New York, New York, 16 February 2009.

Borer, D.A., Everton, S.F., and Nayve, M., "Global Development, Neo-Fundamentalist Islam, and the Future of Freedom: The Rajah Solaiman Movement and Balik Islam in the Philippines," Annual Meeting of the International Studies Association, New York, 14 February 2009.

Everton, S.F., "Network Topography, Key Players, and Terrorist Networks," Annual Meeting of the Association for the Study of Religion, Economics, and Culture, Washington, D.C., 4 April 2009.

Everton, S.F., "Small Worlds, Network Topography, and the Disruption of Dark Networks," Annual Meeting of the IFIP Working Group 7.6 Workshop, Monterey, California, 2009.

Everton, S.F., "The Strategic Application of Social Network Analysis to Dark Networks," Non-Kinetic Targeting DSRC/DARPA Workshop #1, Palo Alto, California, 4 November 2009.

Roberts, N.C., "The CORE Lab and Contributions to Non-Kinetic Targeting," DSRC/DARPA Workshop #1, Palo Alto, California, 4 November 2009.

Roberts, N.C. and Everton, S.F., "Strategies for Combating Dark Networks," Sunbelt XXIX, Annual Meeting of the International Network of Social Network Analysis, San Diego, California, 12 March 2009.

THESES DIRECTED:

Boyden, A.W., Menard, P.P., and Ramirez, R., "Making the Case: What is the Problem with Targeting Killing?" Master's Thesis, Naval Postgraduate School, December 2009.

Dewaele, G., "Social Network Analysis as an Enabler for Information Operations in Afghanistan," Master's Thesis, Naval Postgraduate School, June 2009.

Fekkes, C.C., "Defining Conditions for the Use of Persistent Surveillance," Master's Thesis, Naval Postgraduate School, December 2009.

Gorkowski, J.B., "A Penny for Your Thoughts, a Nickel for your Heart: The Influence of the Command's Emergency Response Program on Insurgency," Master's Thesis, Naval Postgraduate School, December 2009.

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Hargrove, G.M., "Counterinsurgency Operations in Airbase Defense: A Geospatial and Temporal Analysis," Master's Thesis, Naval Postgraduate School, December 2009.

Hartunian, E. and German, W., "Data Integration to Explore the Dynamics of Conflict: A Preliminary Study," Master's Thesis, Naval Postgraduate School, April 2009.

Lewis, R. and Metzger, M., "The SMO-COIN Nexus: Using Social Movement to Demobilize Insurgency," Master's Thesis, Naval Postgraduate School, June 2009.

Putranto, J., "ACEH Conflict Resolution: Lessons Learned and the Future of ACEH," Master's Thesis, Naval Postgraduate School, June 2009.

Singh, D., "Al Qaeda as a Charismatic Phenomenon," Master's Thesis, Naval Postgraduate School, June 2009.

OTHER:

- CORE Lab Workshop on Spatial Regression for NPS students, faculty, and staff 31 August to 4 September 2009.

- Short courses: The CORE Lab sponsored Palantir training for NPS faculty, staff, and students in visual analytics: Palantir Training, 29 August 2009 for 13 attendees; 22 September 2009 for 1 attendee; and 20 October 2009 for 16 attendees.

- CORE Lab Brown Bag Sessions

- Rubin, L., "Egyptian Jihad Reorientation Program," 18 March 2009.
- Bowman, R., "Terrorism and Insurgency in the Philippines," 1 April 2009.
- Noble, C., "Bangsamoro Ethnic Identity: Evolution and Transformation," 9 April 2009.
- Felter, J., "Taking Guns to a Knife Fight," 16 April 2009.

- Dark Web Forum Workshop for selected NPS faculty to introduce Dr. Chen of the AI Lab at the University of Arizona and his research on the Dark Web Forum and to encourage the application of the Dark Web Forum into NPS courses at NPS, 30 November 2009.

WORKING PAPERS:

Anonymous, "Deception," CORE WP-011, 25 September 2009.

Freeman, M., "Islamic Radicalism in Indonesia. A Case Study of the Supply of an Ideology," CORE WP-012, 2 October 2009.

Roberts, N.C., "Brokering Boundaries: Civilian-Military Nexus in the Post-Cold War Era," CORE WP-009, 26 May 2009.

Roberts, N.C., "The Role of Social Entrepreneurs in Post-Conflict Environments," CORE WP-007, 19 January 2009.

Roberts, N.C., "Strategies for Combating Dark Networks," CORE WP-008, 26 March 2009.

Roberts, N.C., "Tracking and Disrupting Dark Networks: Progress, Challenges, Next Steps," CORE WP-010, 30 July 2009.

KEYWORDS: Visual Analytics, Dark Web Forum, Counterterrorism

DEFENSE ANALYSIS

THE JIHADI INFORMATION STRATEGY

Glenn E. Robinson, Associate Professor

Department of Defense Analysis

Sponsor: Joint Information Operations Curriculum, Department of Defense Analysis

OBJECTIVE: To analyze jihadi information strategy and present findings in different forums, culminating in a Stanford University Press book.

SUMMARY: Presented one chapter of a book at a conference on “Rethinking Jihad” at the University of Edinburgh. Overall work on the book is progressing.

CONFERENCE PUBLICATION:

Robinson, G.E., “Jihadi Information Strategy,” *Conference on Rethinking Jihad: Ideas, Politics, and Conflict in the Arab World and Beyond*, University of Edinburgh, September 2009.

KEYWORDS: Information Operations, Information Strategy, Jihad, Jihadism, Jihadi, al-Qa’ida, Usama Bin Laden, Ayman al-Zawahiri

INFORMATION OPERATIONS TO DEFEAT COALITION ENEMIES IN OPERATION

ENDURING FREEDOM FY09 (U)

Hy S. Rothstein, Senior Lecturer

Department of Defense Analysis

Sponsor: Office of the Under Secretary of Defense

OBJECTIVE: To provide direct support to Special Operations units currently deployed in *Operation Enduring Freedom*. A faculty-led student seminar will be in continuous and direct contact with the deployed Special Operations Forces (SOF) Headquarters to develop information operations (IO) plans to support the campaign against coalition enemies. Plan implementation, measuring results and recommending appropriate adjustments are part of this effort. The research group at the Naval Postgraduate School (NPS) will receive all operations and intelligence directly from the supported unit via SIPRNET and JWICS. Frequent classified VTCs with the supported unit will be scheduled. Additionally, in-country visits are scheduled to facilitate program implementation and transition between units. The deliverable will be multiple, detailed, IO plans delivered to the supported unit. The principal investigators plan on using technology currently available to the deployed unit when appropriate. Additional technological support is available through DNI.

INFORMATION OPERATIONS RESEARCH, ANALYSIS, AND OPERATIONAL SUPPORT OF *OPERATION ENDURING FREEDOM*

Hy S. Rothstein, Senior Lecturer

Department of Defense Analysis

Sponsor: Office of Naval Research

SUMMARY: During the last year, the U.S. has sustained its greatest losses in Afghanistan since the war started in 2001. Monthly casualty rates in Afghanistan now exceed those in Iraq. This project involves developing and implementing information operations (IO) through direct and frequent interaction with Special Operations units deployed for *Operation Enduring Freedom*. The ultimate goal is to undermine enemy operations and ensure that U.S. forces maintain the initiative.

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INTEROPERABILITY IN AN IRREGULAR WARFARE WORLD

Anna Simons, Professor

Department of Defense Analysis

Sponsor: Office of the Secretary of Defense-SO/LIC&IC

OBJECTIVE: To develop a new course for CTFP students in the irregular-warfare track.

TEAM MONTEREY: AN ANALYSIS OF IDM SECURITY FOR GROUPS – RED TEAMING ADVERSARY CAPABILITIES AND MOTIVATIONS

David Tucker, Associate Professor

Department of Defense Analysis

Sponsor: Defense Manpower Data Center

OBJECTIVE: The Red Team effort will look at all adversarial threats to Defense Manpower Data Center (DMDC) data. It will look at non-state actors, both criminal and political (i.e., terrorists), and at state actors. In all cases, it will consider the insider threat.

SUMMARY: Phase one (in progress) examines the non-state actor threat, both criminal and political. Phase two will examine the state threat to DMDC data.

DEPARTMENT OF DEFENSE ANALYSIS

**2009
Faculty Publications
and Presentations**

DEFENSE ANALYSIS

JOURNALS

- Arquilla, J., "The Coming Swarm," *New York Times*, 15 February 2009.
- Arquilla, J., "How to Lose a Cyberwar," *Foreign Policy*, December 2009.
- Arquilla, J., "Realities of War," *Third World Quarterly*, Vol. 30, No. 1, 2009.
- Cogan, D.C., "We Fought the Navy and Won: Guam's Quest for Democracy," *Journal of Pacific History*, Honolulu: University of Hawaii Press, 2008, Vol. 44, No. 2, September 2009.
- Everton, S., Borer, D.A., and Nayve, Jr., M.M., "Global Development and Human (In)security: Understanding the Rise of the Rajah Solaiman Movement and Balik Islam in the Philippines," *Third World Quarterly*, 30:181-204, 2009.
- Fox, W., "Judges Commentary," *Consortium*, No. 96, Spring/Summer 2009.
- Fox, W. and Olwell, D., "Contest Director's Article," *Consortium*, No. 96, Spring/Summer 2009.
- Fox, W., Dennis, J.A., Martinez, O.V., Landy, D.C., Malinin, T.I., Morris, P.R., et al., "A Comparison of Two Microbial Detection Methods used in Aseptic Processing of Musculoskeletal Allograft Tissues," *Journal of Cell and Tissue Banking*, October 2009.
- Freeman, M. and Baylouny, A.M., "Tri-Border Area of South America and How Hizbollah is Using the Region for Terrorist Financing," Fall 2009.
- Gregg, H.S., "Beyond Population Engagement: Understanding the Goals of Counterinsurgency," *Parameters*, Vol. 29, No 3, Autumn 2009.
- Gregg, H.S., "Fighting Cosmic Warriors: Lessons from the First Seven Years of the Global War on Terror," *Studies in Conflict and Terrorism*, Vol. 32, No. 3, March 2009.
- Martel, W.C., "Victory in War: Foundations of Military Policy," *Presidential Studies Quarterly*, Cambridge: Cambridge University Press, 2007, March 2009.
- Robinson, G.E., "Jihadi Information Strategy," *Rethinking Jihad: Ideas, Politics, and Conflict in the Arab World and Beyond*, University of Edinburgh, September 2009.
- Simons, A., "The Comanches and Us," *The American Interest*, March-April 2009.
- Tucker, D., "Jihad Dramatically Transformed? Sageman on Jihad and the Internet," *Homeland Security Affairs*, 6, 1, January 2010.

CONFERENCE PUBLICATIONS

- Everton, S., "Violent Extremist Network Representation and Attack the Network Course of Action Analysis in Social Simulation," *Proceedings of the Military Modeling and Simulation (SpringSim) Conference*, 2010.
- Fox, W., "Modeling the Battle of Trafalgar with Discrete Dynamical Systems," *Proceeding of the ICTCM*, Spring 2009.

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PRESENTATIONS

Blanken, L., "The Metric Demon: The Impact of Imperfect Measures of Success on Military Organizations," 2009 ISSS/ISAC Conference, October 2009.

Blanken, L., "Reconciling Strategic Studies...With Itself: A Simple Rationale for Evaluating Strategies," 2009 ISSS/ISAC Conference, October 2009.

Everton, S., "Global Development and Human (In)security: Understanding the Rise of the Rajah Solaiman Movement and Balik Islam in the Philippines," International Studies Association Conference, New York, 15 February 2009.

Everton, S., "Global Development and Human (In)security: Understanding the Rise of the Rajah Solaiman Movement and Balik Islam in the Philippines," Weatherhead East Asian Institute, Columbia University, New York, 16 February 2009.

Everton, S., "Network Topography, Key Players, and Terrorist Networks," Annual Meeting of the Association for the Study of Religion, Economics, and Culture, Washington, D.C., 4 April 2009.

Everton, S., "Small Worlds, Network Topography, and the Disruption of Dark Networks," Annual Meeting of the IFIP Working Group 7.6 Workshop, Monterey, California, 30 September 2009.

Everton, S., "Social Network Analysis: Introduction, Metrics and Strategies," CORE Lab Training for SOCPAC and SOCOM, 4-5 March 2009.

Everton, S., "Social Network Analysis: Introduction, Metrics and Strategies," Presentation to the First Special Operations Group, Ft. Lewis, Washington, 29 October 2009.

Everton, S., "The Strategic Application of Social Network Analysis to Dark Networks," Nonkinetic Targeting DSRC/DARPA Workshop #1, Palo Alto, California, 4 November 2009

Everton, S., "Terror Networks," Presentation to the Officer Development: Center for Seal and SWCC, San Diego, California, 21 July 2009.

Everton, S., "Tracking and Disrupting Dark Networks with Social Network Analysis," NPS/CTFP 2nd Annual Alumni Symposium: Understanding/Targeting Dark Networks, Garmisch-Partenkirchen, Germany, 18 August 2009.

Everton, S. and Borer, D.A., "Global Development, Neo-Fundamentalism, and the Future of Freedom: The Rajah Solaiman Movement and Balik Islam in the Philippines," Annual Meeting of the International Studies Association, New York, New York, 14 February 2009.

Everton, S. and Borer, D.A., "Global Development and the Rise of the Rajah Solaiman and Balik Islam Movements in the Philippines," Weatherhead East Asian Institute, Columbia University, New York, New York, 16 February 2009.

Everton, S. and Roberts, N., "Strategies for Combating Dark Networks," Sunbelt XXIX, Annual Meeting of the International Network of Social Network Analysis, San Diego, California, 12 March 2009.

Fox, W., "An Analysis of Sensing and Identification of Persons and/or Animals Carrying Wires on their Bodies," MAA BIG Session, 15 January 2010.

Fox, W., "The Artist's Guild Strike: An Example of Game Theory," Mathematics Association of America Joint Annual Meeting, Washington, D.C., 5 January 2009.

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Fox, W., "Combat Models: Investigating Solutions using DDS and Lanchester's Equations," MA-INFORMSS, Huntsville, Alabama, April 2009.

Fox, W., "Dynamical Systems Modeling for Iraq," Mathematics Association of America Joint Annual Meeting, Washington, D.C., 7 January 2009.

Fox, W., "Game Theory and KTC Optimization Techniques," INFORMS, 12-14 October 2009.

Fox, W., "Insurgency Models for DA," MAS-INFORMS, Huntsville, Alabama, April 2010.

Fox, W., "Modeling for Combat: Sensing and Identification of Persons Carrying Wires on their Bodies as Part of IEDS Detonation," ICTCM, March 2010.

Fox, W., "Modeling with Game Theory," ICTCM, March 2010.

Fox, W., "The Three Rings of Combat in the Iraq Combat Model," MA-INFORMSS, Huntsville, Alabama, April 2009.

Fox, W., "Wide versus Intralesional Resection of Osseous Renal Cell Metastases," International Society of Limb Salvage/Musculoskeletal Tumor Society, Boston, Massachusetts, 24 September 2009 (poster).

Fox, W. and Vesecky, "Sensing and Identification of Persons and/or Animals Carrying Wires on their Bodies," INFORMS, 12-14 October 2009.

Freeman, M., "Pathways to Terror," International Studies Association, New York, February 2009.

Roberts, N.C. and Everton, S.F., "Strategies for Combating Dark Networks," Sunbelt XXIX, the Annual Meeting of the International Network of Social Network Analysis, San Diego, California, 12 March 2009.

Simons, A., "Anthropology, Culture, and COIN," Culture, Cultural Modeling, Counterinsurgency, and Conflict Behavior, Naval Postgraduate School, 2009.

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WORKING PAPERS

Roberts, N.C., "Brokering Boundaries: Civilian-Military Nexus in the Post-Cold War Era," CORE WP-009, 26 May 2009.

Roberts, N.C., "The Role of Social Entrepreneurs in Post-Conflict Environments," CORE WP-007, 19 January 2009.

Roberts, N.C., "Strategies for Combating Dark Networks," CORE WP-008, 26 March 2009.

Roberts, N.C., "Tracking and Disrupting Dark Networks: Progress, Challenges, Next Steps," CORE WP-010, 30 July 2009.

CONTRIBUTIONS TO BOOKS

Arquilla, J., "Information Wars," *Encyclopedia of Globalization*.

Arquilla, J., "The Promise of Noopolitik," *Handbook of Public Diplomacy*.

Fox, W., "Countering Insurgent Violence," *Winning in Iraq: Understanding the Dynamics of Contemporary War*, J. Arquilla, H. Rothstein, and H. Gregg (Eds.), Potomac Press, 2010 (chapter on Formal Modeling and Modeling Appendix).

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Fox, W., "Solutions Manual and Instructors Guide to the 4th Edition," *4th Edition of a First Course in Mathematical Modeling* (supplement), Belmont, California, 2009.

Gregg, H.S., "U.S. Relations with Islamic Groups in the Middle East," *Handbook of U.S.-Middle East Relations*, R.I. Looney (Ed.), New York: Routledge, 2009.

Robinson, G.E., "Identity Politics and the War in Iraq," *The Three Circles of War: Understanding the Dynamics of Conflict in Iraq*, H.S. Gregg, H.S. Rothstein, and J. Arquilla (Eds.), Herndon, Virginia: Potomac Books, 2010.

Robinson, G.E., "Iraq's Insurgencies in Comparative Perspective," *The Internationalization of Domestic Conflict*, A.L. Freedman (Ed.), Toronto: University of Toronto Press, 2010.

Robinson, G.E., "The Palestinians" *The Government and Politics of the Middle East and North Africa, Sixth Edition*, M. Gasiorowski (Ed.), Boulder, Colorado: Westview Press, 2010.

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Sepp, K., "'To Free the Oppressed' – NATO Special Operations Forces in Future Operations," *Counterinsurgency: The Challenge for NATO Strategy and Operations*, C.M. Schnaubelt (Ed.), Rome: NATO Defense College, 2009.

BOOKS AND SUPPLEMENTAL MATERIALS

Everton, S., *Tracking, Destabilizing and Disrupting Dark Networks with Social Network Analysis: A Manual*, Monterey, California: CORE Lab, Department of Defense Analysis, Naval Postgraduate School, 2009.

Fox, W., *Technology Website for 4th Edition*, supplement to the 4th Edition with Labs and Templates using TI, Maple, MATLAB, Mathematica, and Excel, Cengage Publishing, Belmont, California, 2009.

Fox, W., Giordano, F., Weir, M., and Horton, S., *A First Course in Mathematical Modeling, 4th Edition*, Belmont, California: Cengage Publishing (Brooks-Cole), 2009.

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PUBLISHED REVIEWS

Robinson, G.E., Review of M. Klein's *A Possible Peace between Israel and Palestine: An Insider's Account of the Geneva Initiative*, New York: Columbia University Press, 2007 (review published in the *International Journal of Middle East Studies*, 41, 2009).

Robinson, G.E., Review of B. Milton-Edwards' *The Israeli-Palestinian Conflict: A People's War*, London and New York: Routledge, 2008 (review published in the *Middle East Journal*, 64:1, Winter 2010).

MONOGRAPH

Arquilla, J., "Aspects of Netwar and the Conflict with al Qaeda," for OSD/RRTO, 2009.

DEFENSE ANALYSIS

TECHNICAL REPORT

Gregg, H.S., "Employment Handbook for Fighting Counterinsurgencies – A Toolkit for How to Build Rapport, Create Jobs, and Work towards a Viable State," Naval Postgraduate School Technical Report, NPS-DA-09-001, November 2009.

**DEPARTMENT OF
INFORMATION SCIENCES**

**DANIEL C. BOGER
CHAIRMAN**

INFORMATION SCIENCES

OVERVIEW:

The mission of the Department of Information Sciences is:

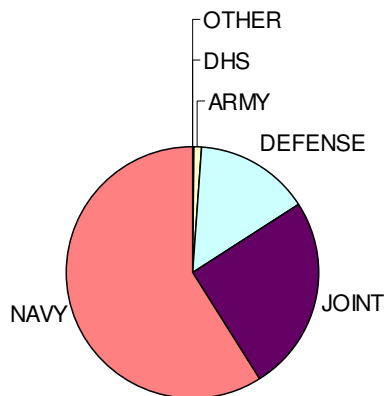
- To provide in-residence graduate education, as well as a continuum of career-long learning opportunities, in support of defense requirements in the areas of information sciences, systems, and operations.
- To maintain an internationally respected research program in selected areas of information sciences, systems, and operations and to develop research programs in additional areas of information sciences that are required to support graduate education.
- To provide expertise and support to the Department of Defense in all areas of information sciences, systems, and operations.

Some of the department's research projects are as follows:

- C3F Science Advisor
- FORCEnet Innovation and Research Enterprise (FIRE)
- Edison VKR TXC Web Service Integration
- Center for Edge Power
- Acquisition Research Program
- Joint Intelligence Virtual University (JIVU)
- Employing Community Models to Deliver Valued Information at the Right Time (VIRT)
- Community Models, Model-Based Communication, and VIRT
- High Precision UAV Target Location Refinement Experiment
- Terrain Database Generation Product Publication
- Coalition Operating Area Surveillance and Targeting System (COASTS)
- Iraqi Enrollment Voice Authentication Program (IEVAP)
- Collaborative Competence
- Management Value Added
- KVA+RO Analysis of Open Architecture Approach
- KVA+RO Software Implementation
- Cognitive Task Analysis of Intelligence Analysts
- Adaptive Architectures for Command and Control
- Joint Intelligence Interoperability Board System Baseline Assessment Project (JSBA)

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Information Sciences is provided below:



Size of Program: \$9M

INFORMATION SCIENCES

Daniel C. Boger
Chair
831-656-3671
dboger@nps.edu

Tarek Abdel-Hamid
Professor
831-656-2678
tkabdelh@nps.edu

Daniel T. Altbaum
Research Associate
831-656-1040
dtaltbaum@nps.edu

Wolfgang Baer
Research Associate Professor
831-656-2209
baer@nps.edu

Albert Barreto
Lecturer
831-656-3072
abarreto@nps.edu

Edgar Bates
Research Associate
eabates@nps.edu

Alexander Bordetsky
Associate Professor
831-656-2287
abordets@nps.edu

Eugene Bourakov
Research Associate
831-656-1120
ebourako@nps.edu

Donald P. Brutzman
Associate Professor
of Applied Science
831-656-2149
brutzman@nps.edu

Rex A. Buddenberg
Senior Lecturer
831-656-3576
budden@nps.edu

Raymond R. Buettner, Jr.
Associate Professor
831-656-3387
rrbuettn@nps.edu

Michael R. Clement
Research Associate
831-656-1804
mrclemen@nps.edu

Glenn Cook
Senior Lecturer
831-656-2778
grcook@nps.edu

Dale M. Courtney
Lecturer
831-214-4353
courtney@nps.edu

Daniel R. Dolk
Professor
831-656-2260
drdolk@nps.edu

James Ehlert
Research Associate
Director, COASTS
International Field
Experimentation Program
831-656-3002
jfehlert@nps.edu

Ray Elliott
Lecturer
831-656-2433
raelliot@nps.edu

Edward Fisher
Lecturer
831-656-3000
elfisher@nps.edu

Shelley P. Gallup
Research Associate Professor
831-656-1040
spgallup@nps.edu

Victor Garza
Lecturer
831-656-3608
vrgarza@nps.edu

Christopher Gunderson
Research Associate Professor
cgunderson@nps.edu

Rick Hayes-Roth
Professor
831-656-3983
fahayesr@nps.edu

Michael A. Herrera
CDR, USN, Military Faculty
Lecturer
831-656-3027
maherrer@nps.edu

Susan Higgins
Lecturer
Deputy Director,
Cebrowski Institute
831-656-3596
slhiggin@nps.edu

Douglas Horner
Research Assistant Professor
831-656-3821
dphorner@nps.edu

Thomas J. Housel
Professor
831-656-7657
tjhousel@nps.edu

Susan G. Hutchins
Research Associate Professor
831-656-3768
shutchins@nps.edu

Steven Iatrou
Senior Lecturer
831-656-3770
sjiatrou@nps.edu

Nelson J. Irvine
Research Assistant Professor
831-656-1007
njirvine@nps.edu

INFORMATION SCIENCES

Erik Jansen
Senior Lecturer
831-656-2623
ejansen@nps.edu

Carl R. Jones
Professor Emeritus
831-656-2995
cjones@nps.edu

Magdi N. Kamel
Associate Professor
831-656-2494
mkamel@nps.edu

William G. Kemple
Associate Professor
831-656-3309
kemple@nps.edu

Anthony Kendall
Lecturer
831-656-3146
wakendal@nps.edu

David L. Kleinman
Professor
831-656-7627
dlkleinm@nps.edu

Douglas J. MacKinnon
Research Associate Professor
831-656-1005
djmackin@nps.edu

Orin E. Marvel
Visiting Associate Professor
831-656-3446
omarvel@nps.edu

William R. Maule
Research Assistant Professor
831-656-3376
rwmaule@nps.edu

Bryan McClain
Research Associate
831-656-3737
bjmcclai@nps.edu

Mark E. Nissen
Professor, C2 Chairman
Director, Center for
Edge Power
831-656-3570
MNissen@nps.edu

Carl L. Oros
Research Associate
831-656-3554
cloros@nps.edu

John S. Osmundson
Associate Professor
831-656-3775
josmundson@nps.edu

Karl D. Pfeiffer
LtCol, USAF
Military Faculty
Assistant Professor
831-656-3635
kdpfeiff@nps.edu

William David Place
Research Associate
619-767-4908
wdplace@nps.edu

William H. Roeting
Research Associate
broeting@nps.edu

Kishore Sengupta
Associate Professor
831-656-3212
kishore@nps.edu

Margaret Schult
CDR, USN, Military Faculty
Director, Information
Professional Center of
Excellence
831-656-3528
mmschult@nps.edu

Diane Smith
Research Associate
831-656-3738
dmsmith@nps.edu

Brian D. Steckler
Lecturer
Associate Chair for
Special Programs
831-656-3837
steckler@nps.edu

John W. Van Hise, Jr.
Research Associate
831-656-3069
jwvanhis@nps.edu

William J. Welch
Lecturer
831-656-3212
wwelch@nps.edu

Brian Wood
Research Associate
831-656-3736
bpwood@nps.edu

Ying Zhao
Research Associate Professor
831-656-3789
yzhao@nps.edu

INFORMATION SCIENCES

INFORMATION SHARING FOR MEDICAL TRIAGE TASKING DURING MASS CASUALTY AND HUMANITARIAN OPERATIONS

**Lillian A. Abuan-Lieutenant Commander, United States Navy
Department of Information Sciences**

Sponsor: Space and Naval Warfare Systems Center-Pacific

SUMMARY: This thesis focused on testing and evaluating the capabilities of a smartphone-based system and associated equipment for “First Responder Networking.” With the use of smartphones as personal servers, data is instantly captured and disseminated in support of first responder operations during humanitarian and mass casualty operations. By using this handheld-based infrastructure, patient information and records can be rapidly passed to those involved within the Mobile Emergency Command Post unit and the Joint Operations Command Center for further backhaul communications from the disaster site to other medical facilities across a globally distributed network; for example, land-based military-medical units, Naval hospital ships, and stateside medical centers.

THE INTEROPERABILITY STANDARDS, COST-EFFECTIVENESS-ANALYSIS TOOL

**Wolfgang Baer, Research Associate Professor
Department of Information Sciences**

Sponsor: MOVES-NMSO

OBJECTIVE: First, to define a model that can be applied by decision makers in order to help them evaluate the cost and benefits of implementing specific interoperability standards; and second, to provide a tool for standards designers to help them optimize features and explain the cost benefits of adopting such standards in terms of tangible dollars and cents to the user community.

SUMMARY: The methodology proposed to develop a standards evaluation tool is quite straightforward. Simply quantify the typical program steps required to receive, interpret, resolve ambiguities, and translate the interoperable-standard message content into the local reference frame with which each of the N programmers operates. Then list the alternative techniques available to the programmer to gain the knowledge required to write the necessary interface code. The list of such techniques ranges from simply looking at an extremely well written standards specification, to searching standards documentation on a web site, to simply talking to colleagues at the water cooler, and every combination in between. Each of these techniques can be quantified in terms of man-hours. Whether or not any specific technique and its associated monetary expenditure are necessary will depend upon the knowledge management environment cast by the characteristics of the applicable standard. This provides a concrete way of mapping standards characteristics to implementation costs as a function of community size and diversity.

In addition, all interoperability standards implementations are effected by machine size, speed, network bandwidth, bit error rate, latency, software maintenance, and various other real-world restrictions. This analysis treats these restrictions on a theoretical level as real-world constraints to an optimization problem that can be quantified with the use of Lagrange’s undetermined multipliers. Although this approach is difficult to quantify, it provides an analysis architecture into which case study results can be logically hung.

KEYWORDS: Interoperability, Message Standards, Cost Effectiveness, System Integration

THE JBAIIC SYSTEM FOR “EMPIRE CHALLENGE”

**Wolfgang Baer, Research Associate Professor
Department of Information Sciences**

Sponsor: Empire Challenge

OBJECTIVE: To support the consultation, review, and recommendation effort for the Network, UAS, Sensor and Command and Control System integration for ISR mission new technologies exploitation and evaluation.

SUMMARY: Provided integration, test, and design support for the JBAIIC Lab at the Naval Postgraduate School, as well as field experiments at Camp Roberts, China Lake, and experimental sites as required. Specific tasks included the evaluation and implementation of message standards, cross domain solutions, and classification information management.

The PVNT UAS system is being modified to be used as a UAV simulator, message test generator, and ISR-target geo-location system during experiment trials. Specific emphasis on message generation, routing, and communication system operations are included in this work.

KEYWORDS: Target Mensuration, Terrain, Battlefield Visualization, Line-of-Sight, Image Processing, Remote Sensing

THE UAV MISSION CONTROL AND SENSOR EXPLOITATION SYSTEM

Wolfgang Baer, Research Associate Professor

Department of Information Sciences

Sponsor: Naval Postgraduate School/CDTEMS

OBJECTIVE: To develop software and an algorithm for the extension and quantification of sensor directed systems to perform surveillance, search, target location, and tracking functions.

The primary goal of this effort is to control and exploit UAV and ground-based sensor capabilities to quantify the accuracy of target tracking and provide sensor data products to operational systems in the field. Included in this project is a built-in UAV simulator and training system. The effort includes the modification of a PVNT (Perspective View Nascent Technologies) software package to digitize input digital video frames, associated camera parameters, provide interactive tracking, and output located target coordinates.

Projects have been divided into two main categories. First are the tasks that support the NPS-UAV team and require integration with NPS UAV capabilities. These are primarily the continued delivery of UAV mission service functions derived from capabilities and operational procedures already developed during previous TNT experiments. The second category of tasks is new or expanded experiments associated with advanced UAV and ISR tasks. These are collected under the title "UAV Mission Control."

NPS UAV Support Tasks: a) Fly-the-Sensor experiments continued; b) complex feature survey and monitoring; c) ISR mission definition experiments for small UAV; and d) portable PVNT UAV Call-in Support Kit.

UAV Mission Control Experiments:

- a. Forward Observer System Test
 - i. Portable PVNT Forward Observer Target Mensuration
 - ii. Expanded UAV interfaces for Target Mensuration
 - iii. Human Interface experimentation
- b. Small UAV Camera Image exploitation
 - i. Terrain product generation for FalconView, PFI, etc.
 - ii. Automated Visual Based Geo-Referencing
 - iii. High-resolution camera image mosaic and visual difference IED detection
- c. Small UAV Mission Control Experiments
 - i. Curser on Target Enabled UAV Simulator
 - ii. CoT ISR Interoperability and Data Format Standardization
 - iii. Simulation and Training Systems in Tactical Command Center Operations

KEYWORDS: Target Mensuration, Terrain, Battlefield Visualization, Line-of-Sight, Image Processing, Remote Sensing

INFORMATION SCIENCES

EXPERIMENTATION WITH THE INTERNATIONAL BENCH PLATFORM: SOCIAL NETWORKING AND COLLABORATIVE SCENARIOS

Alexander Bordetsky, Associate Professor

Department of Information Sciences

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To apply the international bench platform to structuring and operating a globally distributed social network that supports maritime interdiction and special-operation collaborative and expert search scenarios.

TNT-CENTIX STUDENT RESEARCH FOR THE U.S. SPECIAL OPERATIONS COMMAND CENTER FOR NETWORK AND COMMUNICATION

Alexander Bordetsky, Associate Professor

Department of Information Sciences

Sponsor: U.S. Special Operations Command

OBJECTIVE: To explore and field-test solutions for the Special Operations Command Center for Network and Communications research tasks targeting the challenges of collapsing C2, communications, and intelligence systems, and the use and protection of mobile ad hoc networks.

DISTRIBUTED OPERATIONS TACTICAL COMMAND AND CONTROL

Rex A. Buddenberg, Senior Lecturer

Department of Information Sciences

Sponsor: Office of Naval Research

OBJECTIVE: To develop a light-weight, system agnostic data end-user terminal that provides on-the-move, over-the-horizon situation awareness, and command, control, communications, and computers to disadvantaged users operating at the company level and below in support of MCWL's concept-based initiatives.

CONDUCT MDA ITERATIVE SYSTEMS ENGINEERING CHARRETTE TECHNOLOGICAL ASSESSMENT AND LIVE EXPERIMENTATION

Raymond R. Buettner, Jr., Associate Professor

Carl Oros, Research Associate

Department of Information Sciences

Sponsor: Joint Improvised Explosive Device Defeat Organization/GTRI

OBJECTIVE: First, technology assessment assistance will be provided to guide and advise Naval Postgraduate School (NPS) and Joint Improvised Explosive Device (IED) Defeat Organization (JIEDDO) modeling and simulation teams during the development of counter-IED simulation tools. Second, TALE will identify suitable IED and counter-IED technologies for inclusion in live experiments conducted within the TNT program. TALE will coordinate the evaluation of the identified technologies during field experimentation to generate data that can be used to inform/validate/evaluate computational simulation models and tools. The objective of the program is to bridge the gap between micro-level (physics-based) models and macro-level operational simulations to create improved tools for use by the JIEDDO TGT group in its RED/BLUE team activities.

INFORMATION SCIENCES

GLOBAL INFORMATION GRID ENTERPRISE SERVICES MANAGEMENT AND ENGINEERING

Daniel R. Dolk, Professor
Department of Information Sciences
Sponsor: nGAP, Inc.

OBJECTIVE: The Naval Postgraduate School (NPS) and nGAP will work cooperatively on research and development in the area of Global Information Grid (GIG) enterprise services management and engineering. There are three major sub-areas that will comprise this overall effort: services innovation in the Department of Defense (DoD) infrastructure. Services innovation entails both the infrastructure engineering dimension comprised of web services, service-oriented architectures, and network architectures, as well as the organizational dimension, particularly as embodied in the edge organization view. In both cases, services are enablers of new designs, sometimes radically new designs, for existing business processes and services innovation in the DoD.

BIO-RAPIDS

James Ehlert, Research Associate
Department of Information Sciences
Sponsor: Naval Sea Systems Command

SUMMARY: RAPIDS is a low-cost, real-time, multifunctional command and control capability that cost-effectively supports tactical situational awareness, search and rescue, humanitarian assistance, and asset management functions.

COASTS INTERNATIONAL FIELD EXPERIMENTATION SUPPORT TO ENGINEER RESEARCH AND DEVELOPMENT CENTER WORLDWIDE SENSOR TEST AND EVALUATION

James Ehlert, Research Associate
Department of Information Sciences
Sponsor: U.S. Army Corps of Engineers, Engineer Research and Development Center

SUMMARY: A seamless path for 6.1/6.2 research to transition to fully operational CONUS and OCONUS capability does not exist, thus incurring a massive tax in terms of time and cost required to develop and deliver innovative technologies into the warfighter's hands. The logistics, installation, and training of personnel for cutting-edge, prototype C4ISR systems in CONUS and OCONUS environments pose a difficult challenge requiring technical and personnel excellence and tenacity to complete the job. Intermittent communication between multi-agency and national bureaucracies adds further complications and impediments to the efficient development and implementation of C4ISR systems and technologies.

COOPERATIVE OPERATIONS AND APPLIED SCIENCE AND TECHNOLOGY STUDIES: CRIMSON VIPER

James Ehlert, Research Associate
Edward Fisher, Lecturer
Pat V. Sankar, Research Professor
Gurminder Singh, Professor
Department of Computer Science
Sponsor: U.S. Pacific Command

OBJECTIVE: To rapidly deploy and integrate low-cost, state-of-the-art, unclassified, networked air, ground, and maritime sensors providing real-time sensor-to-shooter information to tactical and remote decision-makers: exercise, train, and demonstrate with technology to support counter-drug/counter-terrorism/counter-insurgency operations; demonstrate and promote the operational potential of linked data

INFORMATION SCIENCES

fusion centers; and integration of joint C2 from a tactical to a strategic level. This effort has involved the participation of over 20 students and several staff and other faculty.

The COASTS Field Experimentation Program supports the U.S. Pacific Command (USPACOM), the Joint Interagency Task Force West, the Joint U.S. Military Advisory Group Thailand, the U.S. Special Operations Command, the Naval Postgraduate School, the Royal Thai Armed Forces, and the Thai Defence Science and Technology Office science and technology research requirements relating to theater and national security, counter-drug and law enforcement missions, and the War on Terror.

COASTS 2009 transitioned into the Crimson Viper program and fell under the operational control of USPACOM, and was administered by the MARFORPAC Experimentation Center.

U.S. Sponsors: Office of the Secretary of Defense, U.S. Pacific Command Science Advisor, U.S. Coast Guard Monterey Station, U.S. Coast Guard Maritime Intelligence Fusion Center, Naval Postgraduate School Maritime Domain Protection Research Group, Joint U.S. Military Advisory Group Thailand, Joint Interagency Task Force-West, U.S. Marine Corps Systems Command.

Foreign Sponsors: Thai National Security Council, Defence Science and Technology Office, Military Research and Development Center, Royal Thai Navy, Royal Thai Marines, Royal Thai Air Force, Indonesian Navy.

Commercial Sponsors: Redline Communications, CISCO Systems, MeshDynamics, Mercury Data Systems, Motorola, Western Datacom, Crane, Dynasig, Fortinet, Fortress, Pacific Microwave, Kestrel Technologies, A3IT, ACM, Ambient Micro, Bechtel, CyberDefense UAV, Rotomotion UAV, AeroVironment UAV, Viisage Technology (Formerly Identix), Modular PC.

U.S. MARINE CORPS FORCES PACIFIC EXPERIMENTATION CENTER LOGISTICS AND C4ISR PROGRAM SUPPORT

James Ehlert, Research Associate

Department of Information Sciences

Sponsor: U.S. Marine Corps Experimentation Center

OBJECTIVE: To provide technical analysis and logistics support for the MEC relating to C4ISR program areas and to be demonstrated at Coasts Field Experiment V (19-31 May 2008).

DEPARTMENT OF HOMELAND SECURITY EQUIPMENT INSTALLATION: EMPIRE CHALLENGE 2009

Shelley P. Gallup, Research Associate Professor

Department of Information Sciences

Sponsor: Department of Homeland Security

OBJECTIVE: For the Empire Challenge 09 (EC09) experiment at the Naval Air Weapons Center China Lake, the Department of Homeland Security (DHS), Air and Maritime Unmanned Aircraft Systems (AMUAS) Office will provide a Predator B to demonstrate the aforementioned capability of an “interactive” CIP/CTP.

To satisfy the transport layer requirements for the demonstration, the Naval Postgraduate School will have to establish a VPN node at the CBP AMOC in Riverside, California, to accommodate the movement of FMV and metadata to and from China Lake and the CBP AMOC location in Riverside, California.

DISTRIBUTED, COMMON, GROUND SYSTEM – TASKING, PROCESSING, EXPLOITATION, AND DISTRIBUTION RESEARCH EXPERIMENTATION AND ANALYSIS

Shelley P. Gallup, Research Associate Professor

Department of Information Sciences

Sponsor: U.S. Joint Forces Command

OBJECTIVE: To provide support for the development of TPED management, experimentation processes, and procedures: and experimentation design, execution, data collection, and results during Empire

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Challenge 08 (EC08). The Naval Postgraduate School will work with JFCOM (DII) to create TTPs, C2 infrastructure, and the TPED management experiment.

EMPIRE CHALLENGE/DISE
Shelley P. Gallup, Research Associate Professor
Department of Information Sciences
Sponsor: Deputy Under Secretary of the of Navy

CONFERENCE PUBLICATION:

Hutchins, S.G., MacKinnon, D.J., Freeman, J., and Gallup, S.P., "Maritime Domain Awareness: Assessment of Current Status," *Proceedings of the 14th International Command and Control Research and Technology Symposium*, Washington, D.C., June 2009 (www.dodccrp.org).

PRESENTATION:

Hutchins, S.G., MacKinnon, D.J., Freeman, J., and Gallup, S.P., "Maritime Domain Awareness: Assessment of Current Status," 14th International Command and Control Research and Technology Symposium, Washington, D.C., June 2009 (www.dodccrp.org).

TECHNICAL REPORT:

Hutchins, S.G., MacKinnon, D.J., and Roeting, W.R., "Tasking, Processing, Exploitation, and Dissemination (TPED) Management Findings and Lessons Learned in Empire Challenge 2009," Naval Postgraduate School Technical Report, NPS-IS-09-001, 15 December 2009.

THE JOINT-BATTLESPACE AWARENESS INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE INTEGRATION CAPABILITY (J-BAIIC) EXPERIMENTATION PROGRAM

Shelley P. Gallup, Research Associate Professor
Department of Information Sciences
Sponsor: U.S. Joint Forces Command

OBJECTIVE: This research will include activities related to all efforts in experiment design, data planning requirements, data collection, execution, analysis, and reporting of Trident Warrior 09 (TW09)-related experiments, limited objective experiments, and support activities. The Trident Warrior Experimentation Process developed to date will be further refined based on the TW03 through TW08 experience; this will provide the organizing framework for TW09 (Sea Trial) design, planning, execution, data collection, analysis, reporting, and assessment. A significant portion of this work will be interdisciplinary, with collaboration between Naval Postgraduate School institutes (including faculty and students), SPAWAR, NAVSEA, ONR, NRL, and other agencies, departments, and industrial partners engaged in Sea Trial experimentation.

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THE JOINT-BATTLESPACE AWARENESS INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE INTEGRATION CAPABILITY (J-BAIIC) IN SUPPORT OF EMPIRE CHALLENGE

Shelley P. Gallup, Research Associate Professor
William H. Roeting, Research Associate
Brian Wood, Research Associate
Department of Information Sciences
Sponsor: U.S. Joint Forces Command

SUMMARY: Provided a J-BAIIC KME Experiment Director and appropriate support personnel; exercised oversight of the J-BAIIC KME Project and associated equipment; administered funds for salaries, expenses, travel, equipment, and supplies in support of the J-BAIIC KME Project; provided clerical support, office space, administrative assistance, and office supplies, as required, for the J-BAIIC KME Project; and provided a secure, sheltered bed-down location for the JMSM and related equipment.

PUBLICATIONS:

Irvine, N.J., Jensen, J.J., Roeting, W.H., and Wood, B.P., "Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance (ISR) Integration Capability (JBAIIC), JBAIIC Empire Challenge 2008 Analysis Report," January 2009.

Irvine, N.J., Roeting, W.H., and Jensen, J.J., "JBAIIC Empire Challenge 08 Analysis Report," October 2009.

THE JOINT MULTI-MISSION ELECTRO-OPTIC SYSTEM JOINT CAPABILITIES TECHNOLOGY DEMONSTRATION OPERATIONAL TEST AGENT

Shelley P. Gallup, Research Associate Professor
Brian Wood, Research Associate
Department of Information Sciences
Sponsor: NAVAIR

SUMMARY: Planned and executed two operational demonstrations (OD) in support of the JCTD effort; collected and analyzed data during the ODs; promulgated a joint operational utility assessment (JOUA) report based on the ODs; exercised oversight of the JMMES Project and associated equipment; administered funds for salaries, expenses, travel, equipment and supplies, and contracts in support of the JMMES Project; provided clerical support, office space, administrative assistance, and office supplies, as required, for the JMMES KME Project; observed one technical demonstration (San Diego, February); and coordinated training for airborne OTA observers and airborne subject matter experts.

PUBLICATIONS:

Honegger, B., "University Team Tapped to Test and Evaluate Revolutionary Reconnaissance System," published on Naval Postgraduate School Intranet, 16 June 2009.

Honegger, B., "University Team Tapped to Test and Evaluate Revolutionary Reconnaissance System," *Naval Postgraduate School Outlook Newspaper*, June 2009. (Article subsequently published throughout U.S. Navy publications. Idea and original article submitted by B.P. Wood on the Joint Multi-Mission Electro-Optic System (JMMES) and its Joint Capabilities Technology Demonstration (JCTD) data collection efforts.)

Irvine, N.J., Jensen, J.J., Roeting, W.H., and Wood, B.P., "Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance (ISR) Integration Capability (JBAIIC), JBAIIC Empire Challenge 2007 Analysis Report," January 2009.

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TECHNICAL REPORTS:

Wood, B.P., Gallup, S.P., Jensen, J.J., Irvine, N.J., and Schacher, G., "Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) Demonstration Execution Document (DED) for Operational Demonstration #1-Trident Warrior 09," Naval Postgraduate School Report, 31 May 2009.

Wood, B.P., Gallup, S.P., Jensen, J.J., Irvine, N.J., and Schacher, G., "Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) Demonstration Execution Document (DED) for Operational Demonstration #2-Eglin AFB," Naval Postgraduate School Report, 31 July 2009.

Wood, B.P., Gallup, S.P., Jensen, J.J., Irvine, N.J., and Schacher, G., "Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) 2009 Demonstration Execution Document (DED) Assessment Report (Rough)," Naval Postgraduate School Report, 1 December 2009.

MARITIME DOMAIN AWARENESS SPIRAL-1 CAPABILITY ASSESSMENT AT THE NAVAL POSTGRADUATE SCHOOL

**Shelley P. Gallup, Research Associate Professor
Department of Information Sciences**

Sponsor:

THE NAVAL POSTGRADUATE SCHOOL JOINT BATTLESPACE AWARENESS INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE INTEGRATIONS CAPABILITY KNOWLEDGE-MANAGEMENT AND EXPERIMENTATION PROJECT

**Shelley P. Gallup, Research Associate Professor
Department of Information Sciences**

Sponsor: U.S. Joint Forces Command

OBJECTIVE: The Naval Postgraduate School (NPS) Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance Integrations Capability Knowledge Management and Experimentation (JBAIIC KME) Project, in support of the Field Test and Operations Branch of the Innovation and Experimentation Division of JTC-I, shall provide a knowledge-management and experimentation enterprise that will hypothesize, design, and investigate netcentric ISR integration concepts in support of improved battlespace awareness to facilitate the provision of actionable intelligence to commanders and warfighters at the strategic, operational, and tactical levels of war.

NAVAL POSTGRADUATE SCHOOL SUPPORT TO OPNAV N6F

**Shelley P. Gallup, Research Associate Professor
Department of Information Sciences**

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The Naval Postgraduate School (NPS) Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance Integrations Capability Knowledge Management and Experimentation (JBAIIC KME) Project, in concert with the JFCOM Intelligence, Surveillance, and Reconnaissance (ISR) Division (J28) J-BAIIC, shall provide a knowledge-management and experimentation enterprise that will hypothesize, design, and investigate netcentric ISR integration concepts in support of improved battlespace awareness with the intent being to facilitate the provision of actionable intelligence to commanders and warfighters at the strategic, operational, and tactical levels of war.

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THE NAVNETWARCOM INNOVATION AND EXPERIMENTATION PROGRAM – FORCENET LABORATORY EXPERIMENTS

Shelley P. Gallup, Research Associate Professor
Department of Information Sciences
Sponsor: Naval Network Warfare Command

OBJECTIVE: To support NETWARCOM extension of FORCenet Sea Trial experimentation, including laboratory-based exercises. Two experiments are currently scheduled, to be collectively referred to as “Laboratory Experiments.” The first experiment takes place in fall 2009, with objectives development to begin 1 June. The second experiment will take place in spring 2010. The Naval Postgraduate School will serve as the analysis lead for the experiments.

THE NAVNETWARCOM INNOVATION AND EXPERIMENTATION PROGRAM – TRIDENT WARRIOR AND LIMITED OBJECTIVE EXPERIMENTS (FY09)

Shelley P. Gallup, Research Associate Professor
Department of Information Sciences
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: This research includes activities related to all efforts in experiment design, data planning requirements, data collection, execution, analysis, and reporting of Trident Warrior 09 (TW09)-related experiments, limited objective experiments, and support activities. The Trident Warrior Experimentation Process developed to date will be further refined based on the TW03 through TW08 experience, and will provide the organizing framework for TW09 (Sea Trial) design, planning, execution, data collection, analysis, reporting, and assessment. A significant portion of this work is interdisciplinary; with collaboration between Naval Postgraduate School institutes (including faculty and students), SPAWAR, NAVSEA, ONR, NRL, and other agencies, departments, and industrial partners engaged in Sea Trial experimentation.

NETWORK CENTRIC WARFARE ACCELERATION

Shelley P. Gallup, Research Associate Professor
Department of Information Sciences
Sponsor: Chief Naval Operation, N6F4

OBJECTIVE: The Office of the Chief of Naval Operations, Integration, Interoperability, and Transformation Branch (OPNAV N6F4) is focused on accelerating network centric warfare from concept to deployment. Informed by an understanding of the existing technical challenges and capability gaps, OPNAV N6F4 is responsible for shaping the Navy’s investment strategy in existing communications and computer, intelligence, surveillance, and reconnaissance (C4ISR) programs of record. Additionally, OPNAV N6F4 is responsible for identifying C4ISR technologies that are mature enough to move from the concept exploration/development stage to system demonstration and experimentation. This work is in direct support of OPNAV N6F4.

POST-TRAUMATIC-STRESS DISORDER

Shelley P. Gallup, Research Associate Professor
Douglas J. MacKinnon, Research Associate Professor
Department of Information Sciences
Sponsor:

OBJECTIVE: Post-traumatic-stress disorder (PTSD) represents a growing area of healthcare challenges due to the large numbers of returning war veterans diagnosed with the disorder. This research involves a phased systems-engineering approach to develop a model of VA healthcare delivery for PTSD as an informative case study. The outcome of the study is specifically intended to improve the system of PTSD

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healthcare delivery around measures of performance related to treatment and tracking of patients, as well as near-optimal clinic staffing.

SUPPORT FOR TRIDENT WARRIOR, SEA TRIAL, AND THE FORCENET INNOVATION AND EXPERIMENTATION PROGRAM

Shelley P. Gallup, Research Associate Professor
Department of Information Sciences
Sponsor: Naval Network Warfare Command

SUMMARY: Activities related to all efforts in experiment design, data planning requirements, data collection, execution, analysis, and reporting of Trident Warrior 09 (TW09)-related experiments, limited objective experiments, and support activities. The Trident Warrior Experimentation Process developed to date will be further refined based on the TW03 through TW08 experience, and will provide the organizing framework for TW09 (Sea Trial) design, planning, execution, data collection, analysis, reporting, and assessment.

ARCHITECTURE SUPPORT FOR CMA JCTD AND MIEM

Richard Hayes-Roth, Professor
Department of Information Sciences
Sponsor: Naval Research Laboratory

OBJECTIVE: To assess and improve the CMA JCTD architecture and implementation; to assess and improve the MIEM; to assess and improve the methods for sharing maritime information within and between different agencies and international partners; and to assist in formulating, implementing, and improving alternative methods and technical approaches to high-risk research challenges in the CMA arena, including collaborative development of fusion case files.

DATA STVIRT AND RICH SEMANTIC TRACKS FOR BETTER SHARING AND DECISION-MAKING

Richard Hayes-Roth, Professor
Department of Information Sciences
Sponsor: Naval Research Laboratory

OBJECTIVE: To assess and improve the CMA JCTD architecture and implementation; to assess and improve the MIEM; to assess and improve the methods for sharing maritime information within and between different agencies and international partners; and to assist in formulating, implementing, and improving alternative methods and technical approaches to high-risk research challenges in the CMA arena, including collaborative development of fusion case files.

MIEM DEVELOPMENT AND SUPPORT FOR CMA JCTD

Richard Hayes-Roth, Professor
Department of Information Sciences
Sponsor: Naval Research Laboratory

OBJECTIVE: To help define the highest value objective that CMA can reasonably expect to achieve; and to provide a technological architecture and approach most effective at supporting the development and delivery of such capabilities.

This project aims to create the foundations for community models of maritime information about actionable intelligence, including especially rich semantic tracks corresponding to vessels, cargo, and people. This information develops over time, as a result of fusion and analysis coming from multiple sources. The information evolves into support for cases worthy of boardings and other security responses. The case files must be sharable among and across agencies and international partners. They must support

editing and understanding by humans and machines. This rich semantic model of interesting cases is at the heart of the information sharing problem. Around this sharable information model, the Department of Defense wishes to employ interoperable services that can access, interpret, and augment the evolving information. The goal of this project is to bring an initial set of capabilities to a wide set of users and to lay the foundation for a long-term, unlimited growth in capability. The MIEM will enable users to exchange beliefs and evidence about tracked entities using a standardized semantic model. The MIEM editor will allow agencies to define specialized business documents, such as vessel of interest summaries, and make it easy for operators to read and edit those documents.

AWARDS: Dr. Hayes-Roth was cited as one of the principal contributors when OSD named CMA JCTD the “best managed JCTD on 2008.” Work performed by Dr. Hayes-Roth that contributed directly to this commendation was his work on architecture, scenario-driven focus for service definition, and the development of the MIEM.

KEYWORDS: Information Superiority, Net-Centric Warfare, GIG Services, Community Models, VIRT, Smart Push, Semantics, Ontology, XML Schemas, Interagency and Coalition Information Sharing, MIEM, NIEM

MIEM TRANSITION

Richard Hayes-Roth, Professor
Department of Information Sciences
Sponsor: SPAWAR SYSCEN San Diego

OBJECTIVE: To support the SPAWAR-led team implementing the MIEM in enhancing the model, documenting it, adapting it for use with the NIEM, and making it effective for user communities; to design, develop, and demonstrate tools for reading and editing MIEM documents to support intelligence analysts working in the MDA arena; to provide these tools for users chosen in conjunction with SPAWAR; to evaluate the usability and effectiveness of these tools; and to recommend appropriate follow-on tasks as appropriate.

SUMMARY: The Naval Postgraduate School (NPS) will support the MIEM team at SPAWAR in transitioning the MIEM into successful use by customers designated by the transition team or SPAWAR. NPS will also support the MIEM team at SPAWAR in transitioning the MIEM into the maritime domain model of the NIEM, working in conjunction with collaborators designated by the NIEM Program Office. NPS will interact with various users of shared maritime-intelligence information to improve the conceptual model and information sharing processes, as appropriate. NPS will design, develop, demonstrate, and deliver to MIEM users tools for creating standardized MDA business documents based on MIEM, including tools for viewing and editing those documents. This will include ways to profile and tailor the MIEM for specialized purposes, ways to construct business document templates, and ways to edit and share specific documents that are instances of those templates. This will support collaborative intelligence sharing of maritime intelligence. The principal investigators (PIs) will work with users designated by the MDA COI or SPAWAR to perform Beta testing and continuous improvement on these tools. The PIs will also support those users and evaluate their experiences. Based on lessons learned, the tools will be improved and recommendations will be made for any appropriate follow-on developments.

KEYWORDS: Information Superiority, Net-Centric Warfare, GIG Services, Community Models, Semantics, Ontology, XML Schemas, Interagency and Coalition Information Sharing, MIEM, NIEM, NIEM Maritime, NIEM-M

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NAVAL POSTGRADUATE SCHOOL SUPPORT FOR CMA JCTD

Richard Hayes-Roth, Professor
Department of Information Sciences
Sponsor: Naval Research Laboratory

OBJECTIVE: To assess and improve the CMA JCTD architecture and implementation; to assess and improve MIEM; to assess and improve the methods for sharing maritime information within and between different agencies and international partners; and to assist in formulating, implementing, and improving alternative methods and technical approaches to high-risk research challenges in the CMA arena, including collaborative development of fusion case files.

RAPID PRO VIRT

Richard Hayes-Roth, Professor
Department of Information Sciences
Sponsor: MARCORSYSCOM (PM Intelligence Systems)

OBJECTIVE: The Naval Postgraduate School (NPS) will support the Rapid Prototyping Team (RPT) at MARCORSYSCOM Intelligence Systems. Their objective is to develop and maintain an agile, scalable sub-organization capable of dynamically responding to emergent requirements that balance intelligence “ownership” versus “stewardship.” Specifically, they should seek material and non-material solutions that serve a traditional (doctrinal) intelligence cycle, while simultaneously delivering valuable information at the right time to achieve the right “effects” in order to enable warfighters with “knowledge at the point of action.” RPT requires a disciplined systems architecture, i.e., repeatable best practices and resultant structures, to support this mission. The “Valued Information, Right Time” (VIRT) body of work envisions such an architecture. This project will provide the architecture and technology transition process to support the RPT aims.

Rapid changes in environment, missions, and technology make current systems obsolete and render slow, narrowly focused programs mostly irrelevant. We need to implement an adaptive, evolutionary management of the capability portfolio. Specifically, we want to make most of our capabilities modular and composable while continually combining them in opportunistic ways that address new opportunities and allow us to reinforce valuable components. In short, we want to implement IT applications as if they were a population assembled from a tested and selected pool of “genetic” components. While we have a small population, a limited set of “genes” to work with, and a small number of generations to control, we want to exploit and improve the basic strategy of natural selection applied to our IT components. The high rate of change in the environment, missions, and available IT components make an adaptive approach both desirable and necessary. The technical means of accomplishing this adaptive approach include: 1) an architecture for composing capabilities; 2) a set of evolving components; 3) an environment for testing and employing candidate systems; 4) a fitness function that assesses how well the candidates perform in the environment and that guides feedback; and 5) a feedback function that assures investment flows into successful components and promising new candidates. Because so much of information processing focuses on improving decisions that ultimately yield better outcomes, the fitness function must shape our systems to increase utilization of high-value information and reduce low-productivity activities that produce or consume low-value bits. This, of course, is what our VIRT concepts address: how to assure that significant bits flow to and affect decision-makers while they have time and processing resources to exploit them. Our idea is to create an on-going research program that implements these ideas, supports them with best methods and techniques, and applies them to important defense and government problems. We believe that other groups in the Marine Corps and others in the Department of Defense and throughout government could also benefit from NPS capabilities and research efforts in this line of work. Therefore, we aim to support PM Intel MCSC as an initial means of validating our value and, over time, we plan to seek other partners to improve and grow these capabilities. Specifically, we aim to implement a successful program in service of PM Intel USMC over a three-year period and, during that period, to seek one or two more additional customers who have overlapping needs where we could deliver high value efficiently.

KEYWORDS: Persistent ISR, Tracking, Fusion, DCGS, Collection and Analysis, VIRT, Product-Line Architecture, Agile Methods, Portfolio Management, Risk-Adaptive Systems

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EVALUATION AND IMPLEMENTATION OF THE RAPIDS POINTING MODULE FOR IMPROVED THROUGHPUT/VIDEO QUALITY AND RANGE OF A SMALL, UNMANNED, AERIAL VEHICLE

LT Justin A. Hayward, USN, NPS Student
Department of Information Sciences

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To conduct a system-level test and evaluation of the RAPIDS Pointing Module (RPM) to determine the throughput/video quality and range improvements of small, unmanned, aerial vehicles (SUAV) operating in varied terrain, varied flight paths, and harsh climatic conditions. The RPM is used for directional alignment of antennas, cameras, and other sensors. This improved and inherently secure communication path will better support the ability of SUAV sensor systems (video) to provide more accurate, higher-quality data in the area of interest. This project will utilize a high-gain, directional, narrow-beam antenna to significantly reduce the RF footprint and decrease an enemy's ability to intercept video/data transferred within a fast deployed network. The exploration of the capability to continuously track and align towards an SUAV while extending the range with a static or dynamic ground control station provides a tremendous benefit. It will offer persistent, real-time battlefield surveillance and target identification to improve battle situational-awareness and operational responsiveness. All video and data retrieved by an SUAV, HUMVEE, mobile war fighter, and various sensors will be disseminated within the situational display system RAPIDS.

INFORMATION WARFARE CURRICULUM SUPPORT

CDR Michael A. Herrera, USN, Military Faculty
Department of Information Sciences

Sponsor: Naval Network Warfare Command

SUMMARY: The FY09 information operations/information warfare (IO/IW) funding provided by the Naval Network Warfare Command (NNWC) to the Naval Postgraduate School (NPS) will be used for both faculty labor and student thesis research. Currently, the IW faculty is comprised of a mix of military and civilian faculty, and funding is required to support faculty labor, as required, for teaching, travel in support of JO course development, and thesis advising. Students will use funding provided for experience tour travel and thesis research, including purchasing of hardware/software and equipment for lab facilities to support experimentation and research. Areas of study and research for faculty and students are EW antennae design, radar and communications electronic attack, wireless-networking influence operations, software decoys, influence modeling, web-based influence operations, modeling and simulation in JO, and information assurance. Laboratory facilities include the NPS Wireless Warfare Lab and the "Nemesis" Mobile Research Platform.

ESTIMATING THE VALUE OF OPTIONS IN THE ROLL-OUT OF ADVANCED CAPABILITIES BUILD 12 IN AN OPEN ARCHITECTURE ENVIRONMENT

Thomas J. Housel, Professor
Johnathan C. Mun, Research Professor
Department of Information Sciences

Sponsor: PEO-IWS

OBJECTIVE: To provide return on investment (ROI) and real options analysis to help articulate value proposition in support of the next budget submission cycle for PEO-IWS use of open architecture in upgrading the IWS weapons system(s). In addition, the project will use the Knowledge Value Added + Real Options and Integrated Risk Management (KVA + RO/IRM) methodology, with supporting software, to aid in OA process performance analysis and option value estimation. The customer will select the process(s) and system(s) for the analysis to establish the baseline ROI estimates.

This project will focus on conducting the KVA+RO analysis on the identified upgrade options by working with PEO-IWS 1 personnel to establish the necessary baselines and analyses and to concurrently lay the foundation for developing the level of knowledge necessary for the organization to use and maintain

the toolset going forward. This will ensure that the managers of the process have a decision toolset and the knowledge to interpret the results of the analysis outputs. These include the applications of risk analysis, forecasting, risk hedging and management strategies, strategic real options applications, project portfolio optimization and selection, and other related analytics.

MATHEMATICAL MODELING FOR OPTIMAL SYSTEM TESTING

Thomas J. Housel, Professor
Valery Kanevsky, Agilent Laboratories
Department of Information Sciences
Sponsor: SPAWAR

OBJECTIVE: In the present study, testing is treated as a unified activity, with risk and cost as the common tension regulating the degree of testing required. From a fault-diagnosis perspective, both the cost of module replacement and the cost of testing are considered. The goal is to replace the fewest number of components as quickly as possible, while ensuring that the system is restored to perfect functionality. From a regression testing perspective, particularly with the open architectures employed within the Integrated Warfare System, following component upgrade, the goal is to conduct enough testing to verify that the system remains in perfect function. The element of risk is that costs incurred for perfect knowledge may approach infinity. From a practical perspective, then, it is accepted with some level of confidence (e.g., 99%, 95%) that the diagnosis or prognosis is correct.

THE SPAWAR PROJECT: DEVELOPING A DATA COLLECTION, CODING, AND CLEANSING PROCESS TO ENABLE PERFORMANCE ACCOUNTING AND TOOLS TO SUPPORT THE BUDGETING ALLOCATION PROCESS FOR SIGNAL-INTELLIGENCE COLLECTION SYSTEMS

Thomas J. Housel, Professor
Department of Information Sciences
Sponsor: SPAWAR

OBJECTIVE: This is a continuation of current work on implementing a performance accounting system for the signal-intelligence collection process that will provide routine return on investment (ROI) estimates for CCOP equipment. The goal of this project is to conduct a trial implementation of a performance accounting software that will support collection, ROI reporting, and portfolio optimization for the ongoing performance of Navy signal-intelligence collection systems. The specific goal of this research is to provide data on the operational performance of CCOPs to SPAWAR executive management. Additionally, the results of this continuation of the trial implementation will ultimately aid OPNAV N20 and SPAWAR executives in making decisions during the POM/budgeting process for signal-intelligence systems.

COLLABORATION AND KNOWLEDGE INTEGRATION

Susan G. Hutchins, Research Associate Professor
Department of Information Sciences
Sponsor: Office of Naval Research

SUMMARY: The goal for the Naval Postgraduate School (NPS) Testbed for Team Collaboration Model Validation Project is to understand the role of cognition in teams who are collaborating to solve one-of-a-kind, knowledge-intensive, challenging, ambiguous problems. This is a continuing project, where the objectives for this year's effort were threefold: 1) to empirically evaluate the model of team collaboration based on analysis of real-world, complex, decision-making events, 2) to determine which macrocognitive processes are used and to help refine the model based on empirical analysis, and 3) to better understand how cognition which require rapid action to be taken toward specific mission goals.

Macrocognition describes the way cognition occurs in naturalistic, or real-world, decision-making events. Macro-cognitive functions are generally performed during collaborative-team problem solving, where the emphasis is on building new knowledge. This year, a real-world, complex, decision-making

event and a high-fidelity training exercise were analyzed: NORAD and FAA collaborating to respond to the hijacked airplanes on 11 September 2001, and an Air Force Air Operations Center (AOC) training exercise on dynamic planning and execution involving time-sensitive targeting.

A cognitive model of team collaboration emphasizing the human decision-making processes used during team collaboration (Fiore, Smith-Jentsch, Salas, Warner, and Letsky, 2009) includes collaboration stages, macrocognitive processes and their definitions, and associated metrics. Definitions of the macrocognitive processes included in the measurement model of team collaboration were applied to the team communications that transpired during an AOC exercise on dynamic targeting and to NORAD/FAA collaboration on 9-11. Two students coded both sets of data. There were a total of 2515 and 1517 lines of coding, respectively, for the AOC and NORAD data.

The most significant finding was that a new macrocognitive process emerged during the coding process: *decision to take action*. Deciding to take action is viewed as both a macrocognitive *process* and a *product* of team collaboration. High inter-rater reliability was found for both pairs of coders. Cohen's Kappa coefficient was used to calculate the percentage of agreement between the two coders for both sets of data. Returned Kappa values of .89 and .77, for the AOC and NORAD data, respectively, indicate both pairs of coders interpreted the measurement model of team collaboration in a consistent manner.

PUBLICATION:

Hintze, N. and Hutchins, S.G., "Improving First Responder Problem Solving and Decision Making," *Cognitive Engineering and Decision Making Journal* (in revision).

CONFERENCE PUBLICATIONS:

Hutchins, S.G. and Kendall, T., "Analysis of Team Collaboration across Decision-Making Domains to Empirically Evaluate a Model of Team Collaboration," *Proceedings of the 14th International Command and Control Research and Technology Symposium*, Washington, D.C., June 2009 (www.dodccrp.org).

Hutchins, S.G. and Kendall, T., "Analysis of Team Communications to Understand Cognitive Processes Used during Team Collaboration," *Proceedings of the 15th International Command and Control Research and Technology Symposium*, Santa Monica, California, 22-24 June 2010.

Kendall, T. and Hutchins, S.G., "Use of a Team Collaboration Model in Assessing Knowledge Management Technology," *Proceedings of the 9th International Naturalistic Decision Making Conference*, British Computer Society, London, United Kingdom, 23-26 June 2009.

PRESENTATIONS:

Hutchins, S.G. and Kendall, T., "Analysis of Team Collaboration across Decision-Making Domains to Empirically Evaluate a Model of Team Collaboration," 14th International Command and Control Research and Technology Symposium, Washington, D.C., June 2009 (www.dodccrp.org).

Hutchins, S.G. and Kendall, T., "Analysis of Team Communications to Understand Cognitive Processes Used during Team Collaboration," 15th International Command and Control Research and Technology Symposium, Santa Monica, California, 22-24 June 2010.

Kendall, T. and Hutchins, S.G., "Use of a Team Collaboration Model in Assessing Knowledge Management Technology," 9th International Naturalistic Decision Making Conference, British Computer Society, London, United Kingdom, 23-26 June 2009.

CONTRIBUTION TO BOOK:

Hutchins, S.G. and Kendall, T., "The Role of Cognition in Team Collaboration during Complex Problem Solving," *Informed by Knowledge: Expert Performance in Complex Situations*, K.L. Mosier and U.M. Fischer (Eds.), Taylor and Francis (to appear).

KEYWORDS: Collaboration, Macro cognition, Cognition

THE NAVAL POSTGRADUATE SCHOOL TESTBED FOR TEAM COLLABORATION MODEL VALIDATION

Susan G. Hutchins, Research Associate Professor
Department of Information Sciences
Sponsor: Office of Naval Research

OBJECTIVE: To assist in refining the model of team collaboration developed by Warner, Letsky, and Cowen (2004). The goal is to gain insight into where the model can be improved and to determine how these processes contribute to team performance. The model emphasizes the cognitive aspects of team collaboration and includes the major human decision-making processes used during team collaboration. The goal of this effort is to validate the model by analyzing complex decision-making tasks.

EMPIRE CHALLENGE 2009
Nelson J. Irvine, Research Assistant Professor
Department of Information Sciences
Sponsor:

SUMMARY: The JFCOM Joint Battlespace Awareness ISR Integration Capability (JBAIIC) participation in Empire Challenge experiments is intended to demonstrate the capability and utility of near real-time dissemination, over a cursor-on-target (CoT) network, of relevant intelligence data from a range of dissimilar sensors to tactical commanders. The Naval Postgraduate School performed experiment management, data collection, and analyses in support of JBAIIC.

The focus of JBAIIC participation in EC09 was the integration of Joint Terminal Attack Controllers (JTAC) into the JBAIIC network to provide them with the JBAIIC Common Intelligence Picture/Common Tactical Picture (CIP/CTP) and to demonstrate the utility of the JBAIIC Joint Reconfigurable Vehicle (JRV) in the accomplishment of the JTAC's mission. JTAC communication means (PRC-117F, PRC-117G, Broadband Global Area Network (BGAN), Mobile User Objective System (MUOS), and 3G devices) and JTAC targeting applications (Battlefield Air Operations (BAO) kit, Digital Precision Strike Suite (DPSS), and StrikeLink) were variables in this experimentation.

THE JOINT INTELLIGENCE OPERATIONS CENTER
Nelson J. Irvine, Research Assistant Professor
Department of Information Sciences
Sponsor:

SUMMARY: Participated in the early phases of the project to develop an architecture for the PACOM JIOC. Following a visit to PACOM, a letter report on the PACOM JIOC was prepared.

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THE JOINT MULTI-MISSION ELECTRO-OPTIC SYSTEM

Nelson J. Irvine, Research Assistant Professor

Department of Information Sciences

Sponsor:

SUMMARY: The Naval Postgraduate School (NPS) is the operational test agent (OTA) for the JMMES Joint Technology Capability Demonstration (JCTD). JMMES is an intelligence, surveillance, and reconnaissance (ISR) turret containing five different detectors that, with embedded software, are designed to be able to quickly shift between eight defined mission areas and, consequently, enable reductions in required ISR systems, manning, logistics, and training needed to support operations in these mission areas. The mission areas addressed are: antisubmarine warfare (ASW), surface warfare (SUW), mine counter measures (MCM) – both sea and land, search and rescue (SAR) – both sea and land, counter-camouflage, concealment and deception (CCCD), counter improvised explosive devices (CIED), and illicit crop detection (ICD).

Trident Warrior 2009 (TW09). During TW09, conducted 17-29 June off the coast of Virginia, a JMMES operational demonstration (OD) was conducted in which the ASW, SUW, and maritime SAR mission areas were the subject of the experimentation.

Eglin Air Force Base. A second OD was conducted 21-26 August at Eglin Air Force Base where the MCM (land and sea), land SAR, and CIED mission areas were the subject of the experimentation.

An OTA report on the ODs will be delivered early in 2010; a third, and final, JMMES OD is being planned for execution in conjunction with TW10.

A SEQUENTIAL PATTERN-DETECTION MODEL FOR PREDICTING IMPROVISED EXPLOSIVE DEVICE ATTACKS

Magdi N. Kamel, Associate Professor

Department of Information Sciences

Sponsor: Joint Improvised Explosive Device Defeat Organization Research Program

OBJECTIVE: To use sequential pattern-detection approaches of data mining to develop a predictive model for the timing and frequency of improvised explosive device (IED) attacks. Using the CARMA association rules algorithm on historical data of religious, political, and IED attack events, a model will be developed to explore commonly occurring or high-confidence sequences of events leading to an insurgency IED attack and to predict events that are likely to occur given the sequence observed to date.

SUMMARY: This research used sequence analysis and detection techniques to explore sequences of events leading to IED attacks. Events considered in this research included Government and Infrastructure, Indiscriminate, Iraqi Security Forces, Police, Religious Leaders, and Tribal Leaders attacks. Results indicate the viability of such approaches as an additional tool in the field commander's arsenal to mitigate the effects of IEDs. While the models in their current state are not deployable to operational commands, they eventually could be following a rigorous process of parameters tuning, evaluation, validation, verification, and selection of relevant and appropriate sequences to identify those that are novel, interesting, and useful.

TECHNICAL REPORT:

Kamel, M., "Sequential Pattern Detection Model for Predicting IED Attacks," Naval Postgraduate School Technical Report.

THESIS DIRECTED:

Stafford, W., "Sequential Pattern Detection and Time Series Models for Predicting IED Attacks," Master's Thesis, Naval Postgraduate School, March 2009.

KEYWORDS: IED, Data Mining, Sequence Pattern Detection, CRISP Methodology

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ADAPTIVE ARCHITECTURES FOR COMMAND AND CONTROL

William G. Kemple, Research Associate Professor

Susan G. Hutchins, Research Associate Professor

Lt Col Karl D. Pfeiffer, USAF, Assistant Professor

Department of Information Sciences

Sponsor: Office of Naval Research

OBJECTIVE: The Adaptive Architectures for Command and Control (A2C2) research program has developed a multi-disciplinary research agenda to conduct experimentation on issues critical to maritime operations centers (MOC). Objectives for this year's empirically-focused research were threefold: 1) to continue model-based experimentation; 2) to bring closure on intelligence, surveillance, and reconnaissance (ISR) research questions that emerged in experiment 10; and 3) to explore new paradigms for MOC laboratory research, such as how to effect a plan-play-plan cycle in a controlled laboratory setting.

The research method for the new focus area on MOC C2 structures and processes entails identifying key C2 issues via literature and attendance at MOC events, interacting with the Fleet and other subject matter experts, and analysis of selected points and paths in the research space via A2C2 model-driven experimentation. Potential research issues and questions include identification and exploration of potential "trouble spots" and recommending alternative organizational structures/processes; adaptation and scalability across structures/processes; and coordination with *external* forces and entities/agencies including information and command flows in combined operations and coordination between MOCs.

SUMMARY: A MOC empirical research campaign is underway where the emphasis is on *operational versus tactical* activities, and *planning versus reacting*. Since the MOC was designed to effectively integrate the planning elements of current and future operations (COPS and FOPS) to provide more rapid and accurate resource allocations that are consistent with the mission requirements, the first experiment focused on the MOC with emphasis on ISR. Two alternate structures for ISR personnel are centralized in a stand-alone ISR cell or decentralized by embedding an ISR capability into both the COPS and FOPS cells. Twenty-four participants were partitioned into four teams of six individuals. All teams had three roles, each filled by two participants. These roles abstracted/mimicked personnel in the MOC in charge of COPS, FOPS, and ISR. Each team played in one of two organizational structures. Participants were either separated into two cells (COPS and FOPS, each with an embedded ISR representative) or into three independent cells (COPS, FOPS, and ISR).

Accomplishments during the past year included conduct of a model-based experiment that included: 1) on-going development of a lab environment for A2C2 MOC empirical research, including software tools, communications requirements, and data collection instruments; 2) determining the appropriate pace and methodology for conducting laboratory-based experimentation at the operational level of war, i.e., a slower time-scale with a focus on monitoring, assessing, planning, and directing. This entailed abstracting broad processes flowing through the overall MOC and aggregating 10-100s of staff to a few laboratory participants; 3) forming a realistic linkage to MOC concepts and issues to help guide the experimental focus; 4) conducting the first experiment with emphasis on ISR utilization for operational planning; 5) comparing two alternative ISR organizational structures; 6) conducting liaison to inform Fleet members regarding the A2C2 research program and to gather essential information to inform A2C2 project team members regarding issues of concern to the MOC; and 7) familiarizing Naval Postgraduate School Navy and Marine Corps officer-students with MOC concepts.

CONFERENCE PUBLICATIONS:

Hutchins, S.G., Kemple, W.G., Kleinman, D.L., Miller, S., Pfeiffer, K.D., Horn, Z., et al., "Maritime Operations Centers with Integrated and Isolated Planning Teams," *Proceedings of the 15th International Command and Control Research and Technology Symposium*, Santa Monica, California, 22-24 June 2010.

Hutchins, S.G., Kemple, W.G., Kleinman, D.L., Miller, S., Pfeiffer, K., Weil, S., et al., "Maritime Headquarters with Maritime Operations Center: A Research Agenda for Experimentation," *Proceedings of the 14th International Command and Control Research and Technology Symposium*, Washington, D.C., June 2009 (www.dodccrp.org).

PRESENTATIONS:

Hutchins, S.G., Kemple, W.G., Kleinman, D.L., Miller, S., Pfeiffer, K.D., Horn, Z., et al., "Maritime Operations Centers with Integrated and Isolated Planning Teams," 15th International Command and Control Research and Technology Symposium, Santa Monica, California, 22-24 June 2010.

Hutchins, S.G., Kemple, W.G., Kleinman, D.L., Miller, S., Pfeiffer, K., Weil, S., et al., "Maritime Headquarters with Maritime Operations Center: A Research Agenda for Experimentation," 14th International Command and Control Research and Technology Symposium, Washington, D.C., June 2009 (www.dodccrp.org).

KEYWORDS: Maritime Operations Center, Command and Control, Experimentation

USE OF A TEAM COLLABORATION MODEL IN ASSESSING KNOWLEDGE-MANAGEMENT TECHNOLOGY

Anthony Kendall, Lecturer

Susan G. Hutchins, Research Associate Professor

Department of Information Sciences

Sponsor: Office of Naval Research

SUMMARY: A model of team collaboration was developed that emphasizes the macrocognitive processes entailed in collaboration and includes major processes that underlie this type of communication: 1) individual knowledge building, 2) developing knowledge interoperability, 3) team shared understanding, and 4) team consensus. This research was conducted to empirically validate this model of team collaboration. Additional analysis focused on how collaborative-team problem solving can be enhanced by knowledge management (KM) and collaboration tools. The principal investigators (PIs) described the potential of the analysis conducted by using the definitions of the cognitive processes included in the model of team collaboration to assist in development and selection of components and features to be included in KM and collaboration tools. Data was analyzed for the 9/11 efforts of the Federal Aviation Administration (FAA) in communication with the Northeast Air Defense Sector (NEADS) and the North American Aerospace Defense Command (NORAD), four teams that engaged in air-warfare scenarios, and firefighters from 9-11. Air-warfare scenarios involve identifying air contacts in the combat information center of an Aegis ship.

KEYWORDS: Model of Team Collaboration, Collaboration, Team Decision Making, Communications Analysis

C3F SEA TRIAL/SEA SHIELD EXPERIMENTATION

Richard Kimmel, Research Associate

Department of Information Sciences

Sponsor: Office of Naval Research

SUMMARY: The innovation and experimentation mission of Commander, Third Fleet (COMTHIRDFLT), is to facilitate experimentation in Fleet exercises within the Sea Trial process to support the rapid insertion of innovative and robust Sea Shield concepts and technologies into the Fleet. To accomplish this goal, the principal investigator (PI) supports Sea Trial/Sea Shield program development and provides leadership for the Sea Shield (ASW, MIW, SUW, TAM, AT/FP) Fleet Collaborative Teams (FCTs). COMTHIRDFLT, as operational agent (OA) for Sea Shield, is responsible for the overall prioritization and coordination of all aspects of Sea Shield warfighting concept development and experimentation (CD&E). The PI works to integrate Sea Shield priorities and efforts under a single COMTHIRDFLT authority and manage the development of new Sea Shield concepts and technologies designed to speed the delivery of state-of-the-art warfighting capabilities to the Fleet.

Significant milestones: provided Sea Shield OA oversight, advice, and recommendations to develop policies, design concepts, and establish procedures and goals for the full range of the Sea Trial/Sea Shield Experimentation program; coordinated directly with senior staffs of the CNO, CFFC, and CPF, numbered

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Fleet Commanders, and various flag officers and SES-level personnel in their Sea Shield area of expertise; and ensured that C3F Sea Shield requirements were incorporated into the budgetary and programming process of the Navy and managed Sea Trial experimentation efforts focused on synchronizing warfighter needs with emerging Sea Shield capabilities.

THE JOINT INTELLIGENCE INTEROPERABILITY BOARD SYSTEM

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: Joint Staff J2S/DIA

OBJECTIVE: To study Joint Intelligence Interoperability Board (JIIB) requirements using a systems engineering approach to: identify interoperability issues (technical and process); examine and trade alternate approaches; and provide a direct connection to and assessment of select, on-going, joint intelligence processes and activities. Products produced by the Naval Postgraduate School team (architecture designs, DODAF structures, process models) support future intelligence systems developments and investment strategies.

THE JOINT INTELLIGENCE OPERATIONS CENTER BUSINESS PROCESS MODEL

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: Defense Intelligence Agency

OBJECTIVE: To research the current Joint Intelligence Operations Center (JIOC) enterprise requirements and concepts of employment; to document JIOC information flow and products produced; to perform a detailed architecture decomposition of a JIOC organization; to and develop a swim-lane process model.

THE JOINT INTELLIGENCE OPERATIONS CENTER BUSINESS PROCESS MODEL

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: Defense Intelligence Agency

OBJECTIVE: To research and develop a business process model (BPM) of the PACOM JIOC. JIOCs are the primary intelligence organizations providing support to joint forces at the operational and tactical levels. The JIOC integrates the capabilities of DNI, service, combat support agency, and combatant command intelligence assets to coordinate intelligence planning, collection management, analysis, and support. USD(I) and Director, Enterprise Integration and Information Sharing (Joint Staff J262), tasked the Naval Postgraduate School to research JIOC enterprise operations and document/model (paper) current and potential future business processes within the JIOC enterprise.

SUMMARY: Significant accomplishments: conducted a series of interviews of the PACOM JIOC organization (June–August 2009); researched and developed a baseline BPM architecture structure that highlights organizational structure, operational activities, information flow, systems, and shortfalls (June–September 2009); developed OV-5 Organization swim-lane BPM and documented results (August–September 2009); and completed a final report and delivered the report to the Joint Staff (J262) (December 2009).

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THE JOINT MULTI-MISSION ELECTRO-OPTIC SYSTEM

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: Naval Air Systems Command

OBJECTIVE: To perform operational manager (OM) duties for Commander, Third Fleet, during research and development for the Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) Project.

THE JOINT MULTI-MISSION ELECTRO-OPTIC SYSTEM JCTD OM OPERATIONAL DEMONSTRATION

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: NAVAIR

SUMMARY: The Joint Multi-Mission Electro-Optic System (JMMES) is an FY07 Joint Capabilities Technology Demonstration (JCTD) with the primary objective to demonstrate and transition an automated processing and targeting capability, leveraging existing advanced sensors, for joint coalition and interagency wide-area surveillance needs. The Commander, Third Fleet (C3F), is designated as operational manager (OM) for the JMMES Project. The principal investigator (PI) has the responsibility of coordinating with the management team to ensure that the primary goal of enabling multiple, optimized ISR missions through the development and testing of a common turreted sensor suite is realized. The PI's experience provides the requisite expertise needed to perform OM duties throughout research, development, testing, and analysis of the JMMES.

Significant accomplishments: briefed JMMES JCTD development/demonstration status to ONR Leadership in D.C. (March 2009); briefed JMMES JCTD development/demonstration status to PACOM and USD(ATL) Senior Leadership at PACOM HQ (May 2009); managed FY09 JMMES Operational Demonstrations – ASW, SUW, MSAR during Trident Warrior 09 (June 09) and MCM, LSAR during the effort at Eglin Range (August 2009); managed OPDEMO analysis and reporting for C3F; and coordinated/planned subsequent OPDEMO to be conducted in FY10 in conjunction with RIMPAC/TW10 in HI OPAREA.

JOINT MULTI-MISSION ELECTRO-OPTIC SYSTEMS OPERATIONAL MANAGER SUPPORT TO C3F

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: Naval Air Systems Command

OBJECTIVE: To perform operational manager (OM) duties for Commander, Third Fleet, during research and development for the Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) Project.

THE JOINT SYSTEMS BASELINE ASSESSMENT 09

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: Defense Intelligence Agency

OBJECTIVE: To assess Joint Systems Baseline Assessment (JSBA)-related study requirements and methodologies; to research and develop the required JSBA architecture analyses; to design, develop, organize, and maintain JSBA process model(s) and tools and the associated data; and to execute model run activities and analyze results. The principal investigator will support the development of mission threads and use cases for test and evaluation and will provide analytical support to the JSBA team -ISR/Targeting

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architecture research and process model development that provides direct analyses for a variety of intelligence, surveillance, and reconnaissance assessments as part of JSBA08 efforts and JSBA10 planning.

THE JOINT SYSTEMS BASELINE ASSESSMENT 08/09

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: Defense Intelligence Agency

OBJECTIVE: To assess Joint Systems Baseline Assessment (JSBA)-related study requirements and methodologies; to research and develop the JSBA 08 architecture analyses; and to design, develop, organize, and maintain JSBA process models and tools and the associated data.

UNMANNED AIRCRAFT SYSTEMS SUPPORT TO C3F

Richard Kimmel, Research Associate
Department of Information Sciences
Sponsor: Naval Air Systems Command

OBJECTIVE: To provide subject matter expertise to Commander, Third Fleet, during research and development of all aspects of material/concepts related to unmanned aircraft systems.

DATA MINING RESEARCH OF AGENT TECHNOLOGY

Douglas J. MacKinnon, Research Associate Professor
Department of Information Sciences
Sponsor: Joint Transformation Command

OBJECTIVE: Data mining research of agent technology involves an agent learning technology to train synthetic computer agents to automate the task of recognizing patterns, separating and visualizing important keywords from unstructured data (e.g., text documents), to facilitate and reduce the workload of decision makers and intelligence analysts who would otherwise perform the task manually. The principal investigators (PIs) will also seek to use the agent to help the decision maker's understanding of his complex system by improving and informing his *system self-awareness*. Here, the PIs consider that the cognitive interface between decision makers and a complex system may be expressed in a range of terms or "features," i.e., specific vocabulary to describe a system-of-systems (SoS) or so-called *Lexical Link Analysis (LLA)*. MDA (as an example) is an extremely varied and dynamic SoS, requiring constant collaboration and decision making. The PIs seek to build prototypes of agent learning and collaboration, LLA, and visualization that provide real-time "views" of SoS to support large-scale decision making for MDA technology acquisition, irregular warfare at sea, and intelligence collection with analysis automation.

THE JOINT INTELLIGENCE SURVEILLANCE AND RECONNAISSANCE MANAGEMENT PROCESS

Douglas J. MacKinnon, Research Associate Professor
Department of Information Sciences
Sponsor: Joint Transformation Command

SUMMARY: The Joint Intelligence Surveillance and Reconnaissance (ISR) Management (JISRM) Process is intended to fill an operational gap to effectively and efficiently manage the tasking, processing, exploitation, and dissemination (TPED) of personnel and their related assets in support of ISR requirements within a joint/coalition task force. Efforts in Empire Challenge 2009 (EC09) were intended to provide a fielding and assessment opportunity to test and evolve proposed tactics, techniques, and procedures (TTPs) for improved intelligence tasking, processing, exploitation, and dissemination (TPED) management. A report was prepared summarizing the findings and relaying a significant number of lessons learned that can be applied to the future implementation and assessment of the JISRM management process.

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THE NAVNETWARCOM INNOVATION AND EXPERIMENTATION PROGRAM – TRIDENT WARRIOR AND LIMITED OBJECTIVE EXPERIMENTS (FY09)

Douglas J. MacKinnon, Research Associate Professor

Department of Information Sciences

Sponsor: Joint Transformation Command

OBJECTIVE: Activities related to all efforts in experiment design, data planning requirements, data collection, execution, analysis, and reporting of Trident Warrior 09 (TW-09)-related experiments, limited objective experiments, and support activities. The Trident Warrior Experimentation Process developed to date will be further refined based on the TW03 through TW08 experience, and will provide the organizing framework for TW09 (Sea Trial) design, planning, execution, data collection, analysis, reporting, and assessment. A significant portion of this work is interdisciplinary, with collaboration between Naval Postgraduate School institutes (including faculty and students), SPAWAR, NAVSEA, ONR, NRL, and other agencies, departments, and industrial partners engaged in Sea Trial experimentation.

AN SOA BASELINE ARCHITECTURE ASSESSMENT

William Maule, Visiting Associate Professor

Department of Information Sciences

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To assess SOA infrastructure to determine how SOA-based applications and web services will work in distributed, asynchronous, and synchronous fleet operations. Variables of interest are components, applications, and services in typical fleet and distributed environments. The experimental context will be selected from SOA-based simulation of communications: a) on shore, b) between shore and ship, c) within a ship, and d) between ships.

THE CENTER FOR EDGE POWER

Mark Nissen, Professor

Department of Information Sciences

Sponsor: Office of the Assistant Secretary of Defense–Networks and Information Integration

OBJECTIVE: To foster, coordinate, and promote multidisciplinary research on all elements of network-centric operations (e.g., including concepts, organization, command and control, management, doctrine, personnel, technology).

SUMMARY: In FY04, the Department of Defense (DoD) Command and Control Research Program (CCRP) launched a set of related initiatives designed to explore innovative behaviors, organizations, and technologies, and their implications for command and control (C2). One of these initiatives established the Virtual Edge Institute: a network of research centers located at colleges, universities, and research organizations both within the DoD and in the private sector. The first of these centers—the Center for Edge Power—was established, through funding from the Office of the Assistant Secretary of Defense for Networks and Information Integration (OASD-NII), for innovative C2 research at the Naval Postgraduate School (NPS). Professor Mark Nissen serves as Director.

The Center for Edge Power fosters, coordinates, and promotes multidisciplinary research on all elements of network-centric operations (e.g., including concepts, organization, command and control, management, doctrine, personnel, technology). The term “edge” derives from the seminal book entitled *Power to the Edge* (Alberts and Hayes, 2003), which depicts new ways of organizing military forces and of enabling more powerful warfare by leveraging shared awareness and dynamic knowledge. The central premise is that power (i.e., the capability to accomplish intended actions) needs to flow from the “centers” of military organizations to their “edges.” Using this metaphor, center refers principally to headquarters (e.g., where decision makers request information from the field), and edge refers principally to front lines (e.g., where combatants—at the pointy end of the metaphorical spear—fight wars). The concept clearly involves more than simply realigning organization charts and reallocating decision rights. People at the

edges of organizations must be aware of command intent; know how to accomplish tasks, activities, and processes; and be able to self-organize and self-synchronize to achieve the desired effects.

Although the Center for Edge Power focuses on military organizations and problems, the edge concept also applies well to business, government, and other organizational domains. For instance, the edge of a business organization is where customer interactions take place. Approaches to work, organization, management, and technology other than the Edge will be conceived, investigated, and refined as well, and a fluid flow of concepts and applications, both to and from public- and private-sector organizations, is envisioned to occur.

PUBLICATIONS:

Nissen, M. and Alberts, D., "Toward Harmonizing Command and Control with Organization and Management Theory," *International C2 Journal*, 3:2, pp. 1-59, 2009.

Nissen, M., Bekatoros, N., and Koons, J., "Diagnosing Misfits, Inducing Requirements, and Delineating Transformations within Computer Network Operations Organization," *Cyber-Security and Global Information Assurance: Threat Analysis and Response Solutions*, K. Knapp (Ed.), 2009.

CONFERENCE PUBLICATIONS:

Nissen, M., "Conceptualizing Dynamic Fit and Misfit: Organizational Design Implications," *Proceedings of the Academy of Management Conference*, Chicago, Illinois, August 2009.

Nissen, M. and Powley, N., "Trust-Mistrust as a Design Contingency: Laboratory Experimentation in a Counterterrorism Context," *Proceedings of the International Command and Control Research and Technology Symposium*, Washington, D.C., June 2009 (recommended for Best Paper Award).

PRESENTATIONS:

Nissen, M., "Conceptualizing Dynamic Fit and Misfit: Organizational Design Implications," Academy of Management Conference, Chicago, Illinois, August 2009.

Nissen, M., "ELICIT Research Experience at the Naval Postgraduate School," International Command and Control Research and Technology Symposium, Washington, D.C., June 2009 (invited plenary presentation).

Nissen, M. and Powley, N., "Trust-Mistrust as a Design Contingency: Laboratory Experimentation in a Counterterrorism Context," International Command and Control Research and Technology Symposium, Washington, D.C., June 2009.

KEYWORDS: Command and Control, Edge, Knowledge, Knowledge Flow, Knowledge Management, Knowledge Superiority, Modeling and Simulation, Organizational Design

MEMETICS AND ELICIT TRUST-MISTRUST EXPERIMENTATION

Mark Nissen, Professor

Department of Information Sciences

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: To conduct research to examine trust-mistrust and memetics in defense organizations.

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NEXT GENERATION COMMAND AND CONTROL (NGC2)

Carl Oros, Research Associate
Department of Information Sciences
Sponsor: Office of Naval Research

OBJECTIVE: To focus on emerging candidate-networking technologies applicable for operational integration at the company-level and below. The Naval Postgraduate School (NPS) will explore the network management and formal analysis of these technologies and their implications for small-unit tactical networking through both lab and field research (TNT experiments). Further, building on previous channel experiments, NPS will continue to investigate the physical layer attributes of these technologies as they are made available.

NEXT GENERATION TACTICAL C2

Carl Oros, Research Associate
Department of Information Sciences
Sponsor: Marine Corps Warfighting Lab

SUMMARY: The NGC2 project focused on evaluating emerging candidate networking technologies with potential for operational integration at the Marine Corps Company-level and below. The principal technology evaluated was the TrellisWare software-defined mesh-network device, which the Marine Corps Warfighting Lab has integrated into their limited objective experiments.

THE JOINT SYSTEM BASELINE ASSESSMENT 2009 JOINT INTELLIGENCE COLLECTION MANAGEMENT INTEROPERABILITY PROJECT

John Osmundson, Associate Professor
Department of Information Sciences
Sponsor: Defense Intelligence Agency

SUMMARY: Research was performed under contract in support of the Joint System Baseline Assessment (JSBA) 2009 Joint Intelligence Collection Management Interoperability Project. The key issue identified by JSBA during 2008 was the need to connect command and control (C2) nodes with Defense Common Ground Station (DCGS) capabilities in order to give commanders situational awareness of the joint intelligence, surveillance, and reconnaissance (ISR) process. The principal investigator developed a design for a proposed prototype (based on ISR process modeling) that would provide ISR situational awareness to commanders. Two thesis students developed the prototype, which gathered data from simulated ISR nodes using XML, and then formatted the data into situational awareness screen displays using XML and Java script transformation applications. This work was briefed to ISR experts at SPAWAR San Diego and SPAWAR Charleston, and the response was that the prototype met an important need.

MODELING AND SIMULATION ENGINEERING SOFTWARE AND INFORMATION ASSURANCE MANAGEMENT

Lt Col Karl D. Pfeiffer, USAF, Assistant Professor
Department of Information Sciences
Sponsor: Program Executive Office, Integrated Warfare Systems

OBJECTIVE: Integrated Warfare Systems (IWS) 7E has been assigned responsibility for coordination of enterprise-wide modeling and simulation (M&S) and information assurance (IA) and development of the Collaborative Architecture Simulation Environment (CASE), including assessments in support of Program Executive Office IWS programs. M&S/IA/CASE tasking includes, but is not limited to, threat research, interpretation/development of policy, evaluation of existing procedures, facilitation of technical reviews, requirements analysis, standardization of program documentation, and review and update of enterprise-wide plans to ensure that all program risk has been adequately addressed. Tasking also includes engineering, oversight, and integration of M&S/CASE. Additionally, this task supports the necessary

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coordination of PEO IWS Warfare Systems Readiness Division participation in the various studies and analysis directed by Navy leadership to identify gaps in current warfighting capabilities, develop system engineering solutions to the current and advanced threats, identify threshold and objective values for new systems, and support cost-benefits trade analyses.

THE JOINT MULTI-MISSION ELECTRO-OPTIC SYSTEM

William David Place, Research Associate
Department of Information Sciences
Sponsor: NAVAIR

SUMMARY: The Joint Multi-Mission Electro-Optic System (JMMES) Project is a three-year Naval Postgraduate School initiative. JMMES is an FY08 to FY10 Joint Capabilities Technology Demonstration (JCTD) with the primary objective to demonstrate and transition an automated processing and targeting capability, leveraging existing advanced sensors, for joint coalition and interagency surveillance needs. Commander, Third Fleet (C3F), is designated as the operational manager (OM) for the JMMES Project. C3F has the responsibility of coordinating with the management team to ensure that the primary goal, to enable multiple, optimized ISR missions through the development and testing of a common turreted sensor suite, is realized. The Naval Postgraduate School provides the expertise necessary to perform OM duties throughout research, development, testing, and analysis of the JMMES sensor suite.

UNMANNED AIRCRAFT SYSTEMS

William David Place, Research Associate
Department of Information Sciences
Sponsor: Naval Third Fleet Command

SUMMARY: The principal investigator (PI) serves as a technical advisor to the Third Fleet Commander, VADM Richard Hunt, and effectively facilitates interactions with unmanned aircraft systems (UAS) organizations in government, academia, and industry. The PI assists and advises the Commander and staff in the identification of requirements that will have a critical impact on Fleet operational capabilities, and supports Fleet exercises and experiments where new technology and capabilities are inserted for demonstrations. The PI also supports the Department of Navy (DoN) S&T and R&D communities.

UNMANNED AIRCRAFT SYSTEMS SUPPORT TO C3F

William David Place, Research Associate
Department of Information Sciences
Sponsor: Naval Air Systems Command

OBJECTIVE: To provide subject matter expertise to Commander, Third Fleet, during research and development of all aspects of material/concepts related to unmanned aircraft systems.

JOINT BATTLESPACE AWARENESS ISR INTEGRATION CAPABILITY

William H. Roeting, Research Associate
Department of Information Sciences
Sponsor: U.S. Joint Forces Command - J28

OBJECTIVE: To provide real-time battlespace awareness to the tactical edge through JBAIIC field experimentation and analysis. JBAIIC is a JFCOM J28-sponsored ISR testbed used to promote ISR sensor data integration, as well as intelligence data integration for real-time display at the tactical edge.

SUMMARY: Through a Memorandum of Agreement (MOA) between the Commander, USJFCOM, and the President, Naval Postgraduate School (NPS), the Distributed Information Systems Experimentation (DISE) Group serves as the executive agent for JFCOM J28 ISR field experimentation and analysis. In that

capacity, the DISE Group is responsible for: 1) the discovery of new or existing ISR technology for experimentation, 2) associated research for military applicability, 3) field experimentation execution, 4) objectives development, 5) data collection and analysis planning and execution, 6) data reduction and analysis, and 7) a final report with recommendations.

The MOA is permanent agreement that is reviewed by the principals every two years. DISE is also responsible for the maintenance and servicing of all testbed infrastructure, which currently consists of three mobile trailers, an H2 (Hummer) used for on-the-move experimentation, commercial and tactical radios, and a shop with a variety of tools and equipment to support on-site modifications and maintenance. During FY09, JBAIIC participated in several risk-reduction limited-objective experiments in preparation for Empire Challenge 2009, as well as preliminary limited-objective experiments for SEAL Team 8 deployment in the first quarter CY10, Empire Challenge 2010, Joint Expeditionary Forces Experiment 2010 (JEFX10), and Goose Bay 2010 (GB10) – a NATO ISAF training exercise. For these events, JBAIIC focused on providing an interactive–common intelligence picture/common tactical picture (I-CIP/CTP) to the tactical edge by accessing classified and unclassified IP-based networks to generate air and ground tracks for both Blue and Red forces (to include Link 16 tracks), as well as unmanned aircraft systems (UAS) position and sensor information (to include access to sensor FMV). The JBAIIC I-CIP/CTP was integrated into the Joint Terminal Attack Controller's (JTAC) Battlefield Air Operations (BAO) Kit that is used to support CAS operations by Special Operations Forces (SOF). By incorporating the display of the I-CIP/CTP into the BAO Kit, the JTAC had much better battlefield awareness to enhance fratricide avoidance and mitigate civilian casualties. In order to facilitate the access (LOS and BLOS) to classified and unclassified IP-based networks to collect and display the aforementioned tracks and intelligence data, JBAIIC evaluated several commercial and military IP-based communication systems. They included: the PRC117G with INMARSAT's Broadband Global Area Network (BGAN), the Ericsson 3G QuicLink system, and the replacement to the Department of Defense (DoD) UHF satellite system – the Mobile Utility Objective System. The JBAIIC I-CIP/CTP capability clearly promotes the application of knowledge-management research to the tactical edge for the DoD and the intelligence community.

PRESENTATIONS:

Roeting, R.H., Empire Challenge 2009 Initial Planning Conference, Virginia Beach, Virginia, January 2009.

Roeting, R.H., Empire Challenge 2009 Main Planning Conference, Virginia Beach, Virginia, March 2009.

Roeting, R.H., Empire Challenge 2009 Final Planning Conference, Virginia Beach, Virginia, May 2009.

Roeting, R.H., Empire Challenge 2010 Initial Planning Conference, Virginia Beach, Virginia, December 2009.

Roeting, R.H., NATO Forward Air Controller's Conference, Ramstein Air Force Base, Germany, November 2009.

TECHNICAL REPORTS:

Roeting, W.H. and Irvine, N.J., "U.S. Joint Forces Command (JFCOM), Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance (ISR) Integration Capability (JBAIIC) GMTI Radar Limited Objective Experiment Analysis Report," 28 January 2009.

Roeting, W.H., Irvine, N.J., and Jensen, J.J., "U.S. Joint Forces Command (JFCOM), Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance (ISR) Integration Capability (JBAIIC) Empire Challenge Analysis Report," 3 October 2009.

KEYWORDS: Battlespace Awareness, Network Access, Fratricide Avoidance, Civilian Casualty Mitigation

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THE PATUXENT RIVER ELECTRONIC WARFARE EW-101 CLASS

Lt Col Terry Smith, USAF, Lecturer

Department of Information Sciences

Sponsor: Naval Air Warfare Center-Weapons Division

OBJECTIVE: As a result of the Naval Postgraduate School (NPS) instruction provided at Pt. Mugu in late August, the program manager for the Next Generation Jammer requested that the principal investigator repeat this same instruction to his employees at Patuxent River Naval Air Station in Maryland.

THE PT. MUGU ELECTRONIC WARFARE CLASS

Lt Col Terry Smith, USAF, Lecturer

Department of Information Sciences

Sponsor: Naval Air Warfare Center-Weapons Division

OBJECTIVE: At the request of the Naval Air Warfare Center-Weapons Division (NAWCWD) (Mr. Edgar Becerra and Mr. Thomas Yang), the principal investigator was asked to prepare and present eight hours of instruction at Pt. Mugu in the areas of principles of radar, principles of electronic warfare, and de-coupling and interaction. The NAWCWD conference is from 25-28 August.

TRANSFORMING DATA INTO ACTIONABLE INTELLIGENCE WITHIN THE MARITIME DOMAIN

Joseph J. Sundland, NPS Student

Department of Information Sciences

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To examine a network-centric operations middleware's ability to integrate and fuse together various system and sensor inputs to achieve a comprehensive situational-awareness picture; to assess the middleware's ability to access databases and collect, analyze, and disseminate relevant information to increase situational awareness within the maritime domain; and to evaluate the middleware's ability to support joint Department of Defense and Department of Homeland Security operations within the global maritime environment.

THE NAVAL POSTGRADUATE SCHOOL-JOINT IMPROVISED EXPLOSIVE DEVICES DEFEAT ORGANIZATION BROAD SPECTRUM ANALYSIS PROGRAM

John Van Hise, Jr., Research Associate

Department of Information Sciences

Sponsor: Joint Improvised Explosive Device Defeat Organization Broad Spectrum Analysis Program

SUMMARY: Managed and resourced a multidisciplinary, cross-organizational approach to current causes of insurgencies and the networks that support the use of various types of improvised explosive devices (IEDs). This included, but was not limited to, social and political analyses, red teaming, modeling and simulation, operations research, systems engineering, and business analysis to define and study the key nodes and arcs of underlying networks from which the use of IEDs emerge, thereby significantly reducing their tactical and operational impact and eventually eliminating their strategic influence.

The JIEDDO Program consists of a variety of collaborative research efforts that include faculty and researchers from all disciplines and schools and at the Naval Postgraduate School. It is currently reaching out to other Department of Defense and private research institutions via the newly established National Security Institute. This will expand the resources and knowledge-base to counter emerging threats to national and homeland security. It is planned that the JIEDDO Program will be the model for development of other initiatives under NSI.

KEYWORDS: Interdisciplinary Research, Modeling and Simulation, Red Teaming, Counter Insurgency, Improvised Explosive Device, IED

INFORMATION SCIENCES

THE BIO-PEN AND PRIVATE LOCK INFRASTRUCTURE

LCDR Michael S. Zanger, USN, NPS Student

Department of Information Sciences

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To focus on the continued testing and verification of a new, signature-based biometric-technology system for authentication and verification – bio-pen and private lock infrastructure.

REAL-TIME PROGRAM SELF-AWARENESS FOR AGILE ACQUISITION OF C4I SYSTEMS

Ying Zhao, Research Associate Professor

Shelley P. Gallup, Research Associate Professor

Douglas J. MacKinnon, Research Associate Professor

Anthony Kendall, Lecturer

Department of Information Sciences

Sponsor:

OBJECTIVE: Department of Defense acquisition is an extremely complex system, comprised of myriad stakeholders, processes, people, activities, and organizations in an effort to provide the most useful capabilities to warfighters at the best possible value to the government. This research considers that the cognitive interface between decision makers and a complex system may be expressed in a range of terms or “features,” i.e., a specific vocabulary to describe the attributes and surrounding environment of a system. A data-driven automation method will be presented, namely, a Lexical Link Analysis (LLA), to automate so-called system self-awareness. This effort can allow decision makers to be aware of what programs, systems, and specific features are available for acquisition and how well they match with warfighters’ needs and requirements with greater immediacy – possibly in real-time.

DEPARTMENT OF INFORMATION SCIENCES

**2009
Faculty Publications
and Presentations**

JOURNALS

Dwyer, C., Hayes-Roth, R., et al., "A Maritime Information Exchange Model (MIEM) for Sharing Actionable Intelligence," *2009 NRL Review*, J.D. Bultman (Ed.), Washington, D.C., Naval Research Laboratory, 2010.

Hayes-Roth, F., "Getting More Bang for the Buck," *IEEE Spectrum*, 46(1): 10, 2009.

Nissen, M. and Alberts, D., "Toward Harmonizing Command and Control with Organization and Management Theory," *International C2 Journal*, 3:2, pp. 1-59, 2009.

Rodgers, W. and Housel, T.J., "Problems and Resolutions to Future Knowledge-Based Assets Reporting," *Journal of Intellectual Capital*, Vol. 10, No. 4, 2009.

PUBLICATIONS

Kimmel, R.A. and Place, D., *JMMES JCTD Concept of Operations*, May 2009.

Kimmel, R.A. and Schacher, G., *PACOM JIOC Business Process Model*, December 2009.

Sankar, P. and Ferrari, L., "Beyond the State of the Art of Compression," 14 September 2009.

CONFERENCE PUBLICATIONS

Baer, W., "Effectiveness Metrics and Cost Benefit Analysis Methodology for Machine-to-Machine Interoperability Standards," SPIE Defense and Security Symposium, Orlando, Florida, 13-17 April 2009, Paper #7352A-25, *Intelligent Sensing, Situation Management, Impact Assessment, and Cyber-Sensing*, J.F. Buford, G. Jakobson, S. Mott, and M.J. Mendenhall (Eds.), *Proceedings of SPIE*, Vol. 7352 73520R.

Baer, W., "Live/Virtual Cognitive Systems Simulation," *Proceedings of the 9th WSEAS International Conference on Applied Computer Science*, Genova, Italy, 17-19 October 2009 (<http://www.wseas.us/books/2009/genova/ACS.pdf>).

Baer, W. and Koelsch, M., "Shadow and Feature Recognition Aids for Rapid Image Geo-Registration in UAV Vision System Architectures," SPIE Defense and Security Symposium, Orlando, Florida, 13-17 April 2009, Paper #7336-41, *Signal Processing, Sensor Fusion, and Target Recognition XVIII*, I. Kadar (Ed.), *Proceedings of SPIE*, Vol. 7336, 733613.

Baer, W. and Pizzi, R., "The Case for Biological Quantum Computer Elements," SPIE Defense and Security Symposium, Orlando, Florida, 13-17 April 2009, Paper #7342A-3, *Quantum Information and Computation VII*, E.J. Donkor, A.R. Pirich, and H.E. Brandt (Eds.), *Proceedings of SPIE*, Vol. 7342, 734204.

Bourakov, E. and Bordetsky, A., "Voice-on-Target: A New Approach to Tactical Networking and Unmanned Systems Control via the Voice Interface to the SA Environment," *14th International Command and Control Research and Technology Symposium, C2 and Agility*, Washington, D.C., 17 June 2009.

Bourakov, E., Yakimenko, O., and Slegers, N., "Exploiting a GSM Network for Precise Payload Delivery," *20th Aerodynamic Decelerator Systems Technology Conference and Seminar*, Seattle, Washington, 7 May 2009.

Demir, K.A., Michael, J.B., and Osmundson, J.S., "Approaches for Measuring Software Project Management Effectiveness," *2009 World Congress in Computer Science, Computer Engineering, and Applied Computing*, Las Vegas, Nevada, 13-16 July 2009.

Hutchins, S.G. and Kendall, T., "Analysis of Team Collaboration across Decision-Making Domains to Empirically Evaluate a Model of Team Collaboration," *Proceedings of the 14th International Command and Control Research and Technology Symposium*, Washington, D.C., June 2009 (www.dodccrp.org).

Hutchins, S.G. and Kendall, T., "Analysis of Team Communications to Understand Cognitive Processes used during Team Collaboration," *Proceedings of the 15th International Command and Control Research and Technology Symposium*, Santa Monica, California, 22-24 June 2010.

Hutchins, S.G., MacKinnon, D.J., Freeman, J., and Gallup, S.P., "Maritime Domain Awareness: Assessment of Current Status," *Proceedings of the 14th International Command and Control Research and Technology Symposium*, Washington, D.C., June 2009 (www.dodccrp.org).

Hutchins, S.G., Kemple, W.G., Kleinman, D.L., Miller, S., Pfeiffer, K., Weil, S., et al., "Maritime Headquarters with Maritime Operations Center: A Research Agenda for Experimentation," *Proceedings of the 14th International Command and Control Research and Technology Symposium*, Washington, D.C., June 2009 (www.dodccrp.org).

Huynh, T.V. and Osmundson, J.S., "Predicting Outbreak of Economic Malaise in Financial Networks," *2009 INCOSE International Symposium*, Singapore, 20-24 July 2009.

Huynh, T.V., Osmundson, J.S., and Tran, X.L., "Architecting of Systems of Systems for Delivery of Sustainable Value," *MIT Engineering Systems Symposium*, Cambridge, Massachusetts, 17 June 2009.

Jansen, E., Hocevar, S.P., Rendon, R.G., and Thomas, G.F., "The Theory and Measurement of Interorganizational Collaborative Capacity in the Acquisition and Contracting Context," *Proceedings of the 6th Annual Acquisition Research Symposium*, Monterey, California, May 2009.

Kendall, T. and Hutchins, S.G., "Use of a Team Collaboration Model in Assessing Knowledge Management Technology," *Proceedings of the 9th International Naturalistic Decision Making Conference*, British Computer Society, London, United Kingdom, 2009.

Kendall, T. and Hutchins, S.G., "Use of a Team Collaboration Model to Identify Candidate Knowledge Management and Collaboration Technologies," *Proceedings of the 9th Bi-Annual International Conference on Naturalistic Decision Making*, British Computer Society, London, United Kingdom, 23-26 June 2009.

Nissen, M., "Conceptualizing Dynamic Fit and Misfit: Organizational Design Implications," *Proceedings Academy of Management Conference*, Chicago, Illinois, August 2009.

Nissen, M. and Powley, N., "Trust-Mistrust as a Design Contingency: Laboratory Experimentation in a Counterterrorism Context," *Proceedings of the International Command and Control Research and Technology Symposium*, Washington, D.C., June 2009 (recommended for Best Paper Award).

Osmundson, J., "Approaches to Analyzing Emergent Behavior of a System-of-Systems," Panel: How to Engineer the Emergent Behavior of a System of Systems (invited panel member and talk), *2009 INCOSE International Symposium*, Singapore, 20-24 July 2009.

Osmundson, J.S., Langford, G.O., and Huynh, T.V., "Emergent Behavior in an Unregulated Financial System of Systems: Economic Meltdown," *2009 INCOSE International Symposium*, Singapore, 20-24 July 2009.

Pfeiffer, K., Kanevsky, V., and Housel, T., "Testing of Complex Systems: Information-Driven Strategies to Reduce Cost and Improve Reliability," *Proceedings of the INFORMS Annual Meeting*, San Diego, California, 11-14 October 2009.

PRESENTATIONS

Baer, W., "Applications of an Integrated Mind-Body Model of Consciousness," Science and Nonduality Conference, San Rafael, California, 23-25 October 2009.

Baer, W., "Effectiveness Metrics and Cost Benefit Analysis Methodology for Machine-to-Machine Interoperability Standards," SPIE Defense and Security Symposium, Orlando, Florida, 13-17 April 2009.

Baer, W., "Live/Virtual Cognitive Systems Simulation," 9th WSEAS International Conference on Applied Computer Science, Genova, Italy, 17-19 October 2009.

Baer, W., "Shadow and Feature Recognition Aids for Rapid Image Geo-Registration in UAV Vision System Architectures," SPIE Defense and Security Symposium, Orlando, Florida, 13-17 April 2009.

Baer, W. and Pizzi, R., "The Case for Biological Quantum Computer Elements," SPIE Defense and Security Symposium, Orlando, Florida, 13-17 April 2009.

Gallup, S., "DISE Research: DHS Relevant Research," presented to Under Secretary for the Department of Homeland Security, Monterey, California, 9 April 2009.

Gallup, S.P., Irvine, N.J., and Wood, B.P., "Joint Multi Mission Electro-Optic System (JMMES) Joint Capabilities Technology Demonstration (JCTD) Results," presented to Commander, Third Fleet, Staff and NAVAIR Staff, San Diego, California, 16 December 2009.

Gallup, S.P., MacKinnon, D., Zhao, Y., Robey, J., and Odell, C., "Facilitating Decision Making, Re-Use and Collaboration: A Knowledge Management Approach for System Self-Awareness," International Joint Conference on Knowledge Discovery, Knowledge Engineering, and Knowledge Management, Madeira, Portugal, 6-8 October 2009.

Hayes-Roth, F., "Evolutionary Adaptive Development: A New Foundation for Creating Intelligent Complex Systems," Singularity University, NASA Ames, Mountain View, California, 2009.

Hayes-Roth, F., "The National and International 'Information Sharing Problem': Using XML to Enable Conceptual Modeling, Sharing, and Collaboration of 'Business Documents'," Oracle, Redwood Shores, California, 2009.

Hayes-Roth, F., "Testing Evolutionary Development: Top 10 Good and Bad Ways to Evolve," DISA Customer Participation Conference, JITC Track, DISA JITC, 2009.

Hutchins, S.G. and Kendall, T., "Analysis of Team Collaboration across Decision-Making Domains to Empirically Evaluate a Model of Team Collaboration," International Command and Control Research and Technology Symposium, Washington, D.C., June 2009 (www.dodccrp.org).

Hutchins, S.G., MacKinnon, D.J., Freeman, J., and Gallup, S.P., "Maritime Domain Awareness: Assessment of Current Status," 14th International Command and Control Research and Technology Symposium, Washington, D.C., June 2009 (www.dodccrp.org).

Hutchins, S.G., Kemple, W.G., Kleinman, D.L., Miller, S., Pfeiffer, K., Weil, S., et al., "Maritime Headquarters with Maritime Operations Center: A Research Agenda for Experimentation," 14th International Command and Control Research and Technology Symposium, Washington, D.C., June 2009 (www.dodccrp.org).

Kamel, M., "Building and Sustaining Integrity in Defense Decision Making," 21st Century Defense and Armaments Policy Issues and Challenges Conference, Rabat, Morocco, 15-17 April 2009.

INFORMATION SCIENCES

Kamel, M., "Ontology-Aided Knowledge Discovery Assistant (OAKDA)," Fifth International Conference on Knowledge Capture, Redondo Beach, California, 1-4 September 2009.

Kendall, A. and Hutchins, S.G., "Use of a Team Collaboration Model in Assessing Knowledge Management Technology," 9th International Naturalistic Decision Making Conference, British Computer Society, London, United Kingdom, 2009.

Kendall, A. and Hutchins, S.G., "Use of a Team Collaboration Model to Identify Candidate Knowledge Management and Collaboration Technologies," 2009 Naturalistic Decision Making Conference, London, United Kingdom, 25 June 2009.

Kimmel, R.A., "C3F Technology Requirements," ONR S&T Conference, June 2009.

Kimmel, R.A., "JMMES JCTD Program Brief," ONR, March 2009.

Kimmel, R.A., "JMMES JCTD Program Brief," PACOM, May 2009.

MacKinnon, D., "DISE Research in FY09," hosted by the Chief of Naval Operations and given at the Office of Naval Research and the Army/Navy Country Club in Washington D.C., in support of the NPS Centennial Celebration, 9-10 September 2009 (invited).

MacKinnon, D., "DISE Thesis Topics," Thesis Seminar for Information Science (IS 3333), Monterey, California, 12 February 2009 (invited).

MacKinnon, D., "DISE Thesis Topics," Thesis Seminar for Information Science (IS 3333), Monterey, California, 20 August 2009 (invited).

MacKinnon, D., "How Individual Skill Growth and Decay Affect the Performance of Project Organizations: A Ph.D. Level Experience at Stanford University," Department of Information Sciences Weekly Ph.D. Research Seminar (IS4790), Monterey, California, 11 February 2009 (invited).

MacKinnon, D., "MOC Issues: Architecture and Other Issues," Policies and Problems in C4I JC4I Capstone Course (CC 4913) for Information Science, Monterey, California, 8 April 2009 (invited).

MacKinnon, D. and Gallup, S., "DISE Research: DHS Relevant Research," presented to the Under Secretary for the Department of Homeland Security, Monterey, California, 9 April 2009 (invited).

MacKinnon, D., Utschig, J., Garza, R., and McClain, B., "DISE Capabilities and Accomplishments," Naval Postgraduate School Centennial Celebration, Monterey, California, 25 May 2009.

MacKinnon, D., Zhou, C., Zhao, Y., and Kotak, C., "The Collaborative Learning Agent (CLA) in Trident Warrior 08 Exercise," poster session, International Joint Conference on Knowledge Discovery, Knowledge Engineering, and Knowledge Management, Madeira, Portugal, 6-8 October 2009.

Nissen, M., "Dynamic Knowledge Principles and Learning Army Organizations: How Unthinkable?" Army Operational Knowledge Management Conference, Kansas City, Missouri, October 2009 (invited).

Nissen, M., "ELICIT (Experimental Laboratory for Investigating Collaboration, Information-Sharing, and Trust) Experimentation in a Virtual Environment: Some Preliminary Design Thoughts," MOVES Institute Seminar, Monterey, California, May 2009 (invited).

Nissen, M., "ELICIT Research Experience at the Naval Postgraduate School," International Command and Control Research and Technology Symposium, Washington, D.C., June 2009 (invited).

Nissen, M., "ELICIT Research Opportunities at the Army Research Laboratory," U.S. Army Research Laboratory, Adelphi, Maryland, June 2009 (invited).

Nissen, M., "Information Propagation, Impact, and Persistence: Organizational Design and Trust Implications," DARPA Memetics Seedling Research Meeting, Arlington, Virginia, February 2009 (invited).

Nissen, M., "Knowledge Dynamics: Key Principles for Afloat Knowledge Managers," Navy Afloat Knowledge Managers Course, San Diego, California, December 2009 (invited).

Nissen, M., "Knowledge Management," Information Professional Center of Excellence Senior Officer Course, Monterey, California, August 2009 (invited).

Nissen, M., "Knowledge Management Concepts and Training: Operational IM-KM Focus," U.S. Marine Corps Information Management Conference, Camp Pendleton, California, October 2009 (invited).

Nissen, M., "Research Centres and Knowledge: The Good, the Bad, and the Ugly," Monieson Centre, Queens University, Kingston, Ontario, Canada, May 2009 (invited).

Place, W.L., AUVSI Board of Directors Meeting, May 2009.

Place, W.L., AUVSI Board of Directors Meeting, September 2009.

Place, W.L., AUVSI Board of Directors Meeting, December 2009.

Place, W.L., Fleet UAS Requirements Discussions with Representatives from CNO's Strategic Studies Group, April 2009.

Place, W.L., JMMES Operational Program Management Review with Operational Test Agent Team, November 2009.

Place, W.L., Multiple Briefs to Third Fleet Staff, Providing Overviews of New UAS Technologies/Capabilities, 2009.

Place, W.L., Navy STUAS Requirements Discussions with Naval Air Force, Naval Surface Force, and Industry Personnel, October 2009.

Place, W.L., Navy UAS Requirements Discussions with Joint Forces Command Personnel, December 2009.

Place, W.L., Navy UAS Requirements Discussions with Navy Research Lab Personnel, November 2009.

Place, W.L., Navy UAS Requirements Discussions with Shee Atika Technology Personnel, September 2009.

Place, W.L., Navy UAS Sensor Discussions with Naval Surface Force, Naval Special Warfare Group, and Goodrich Personnel Regarding SWIR (Short Wave Infrared), December 2009.

Place, W.L., Operational ISR Requirements Discussions with JMMES Integrated Management Team, May 2009.

Place, W.L., STUAS (Small Tactical Unmanned Aircraft Systems) Requirements Discussions with Commander, Naval Surface Force, and Commander, Tactical Group ONE, Staff Personnel, February 2009.

Place, W.L., STUAS (Small Tactical UAS) Operational Requirements Discussions with Commander, Naval Surface Force Staff, September 2009.

Wood, B., "Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) 2009 Demonstration Execution Document (DED) Assessment Report," presented to Commander, Third Fleet, N9, 16 December 2009.

CONTRIBUTIONS TO BOOKS

Nissen, M. and Ibrahim, R., "Developing a Knowledge-Based Organizational Performance Model for Improving Knowledge Flows in Discontinuous Organizations," *Knowledge Management, Organizational Memory and Transfer Behavior: Global Approaches and Advancements*, M. Jennex (Ed.), Hershey, Pennsylvania: GIGlobal, pp. 89-108, 2009.

Nissen, M., Bekatoros, N., and Koons, J., "Diagnosing Misfits, Inducing Requirements, and Delineating Transformations within Computer Network Operations Organization," *Cyber-Security and Global Information Assurance: Threat Analysis and Response Solutions*, K. Knapp (Ed.), 2009.

Oros, C.L. and Nissen, M.E., "Designing Complex Organizations Computationally," *Handbook of Research on Complex Dynamic Process Management: Techniques for Adaptability in Turbulent Environments*, ISBN: 978-1-60566-669-3; 689 pp; July 2009.

BOOK REVIEW

Nissen, M., "Book Review: *Knowledge Management – Systems Implementation: Lessons from the Silicon Valley*, by Hind Benbya," *Knowledge Management Research and Practice*, 7:2, 2009. (Note: this book review appears in a refereed journal, but the piece itself was subject to only editorial- not peer-review.)

PATENTS

Bourakov, E., "Method and Apparatus for Large Scale Wild Fire Extinguishing," Patent, 2009.

Hayes-Roth, F., "Hook-Up Assistant," U.S. Patent 7,552,393 B2, 2009.

TECHNICAL REPORTS

Hutchins, S.G., MacKinnon, D.J., and Roeting, W.R., "Tasking, Processing, Exploitation, and Dissemination (TPED) Management Findings and Lessons Learned in Empire Challenge 2009," Naval Postgraduate School Technical Report, NPS-IS-09-001, 15 December 2009.

Irvine, N., "Joint BattleSpace Awareness ISR Integration Capability (JBAIIC) Empire Challenge 2009 Analysis Report," October 2009.

Irvine, N., Letter report on the PACOM JIOC, 15 June 2009.

Irvine, N.J., Jensen, J.J., Roeting, W.H., and Wood, B.P., "Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance (ISR) Integration Capability (JBAIIC), JBAIIC Empire Challenge 2007 Analysis Report," January 2009.

Kamel, M., "Sequential Pattern Detection Model for Predicting IED Attacks," Naval Postgraduate School Technical Report, 2009.

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Nissen, M., "Dynamic Fit and Misfit through Organizational Design: Conceptualization via Stability and Maneuverability," Naval Postgraduate School Technical Report, NPS-46-09-001, June 2009.

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Roeting, W.H. and Irvine, N.J., "U.S. Joint Forces Command (JFCOM), Joint Battlespace Awareness Intelligence, Surveillance, and Reconnaissance (ISR) Integration Capability (JBAIIC) GMTI Radar Limited Objective Experiment Analysis Report," 28 January 2009.

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Wood, B.P., Gallup, S.P., Jensen, J.J., Irvine, N.J., and Schacher, G., "Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) Demonstration Execution Document (DED) for Operational Demonstration #1-Trident Warrior 09," Naval Postgraduate School Report, 31 May 2009.

Wood, B.P., Gallup, S.P., Jensen, J.J., Irvine, N.J., and Schacher, G., "Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) Demonstration Execution Document (DED) for Operational Demonstration #2-Eglin AFB," Naval Postgraduate School Report, 31 July 2009.

Wood, B.P., Gallup, S.P., Jensen, J.J., Irvine, N.J., and Schacher, G., "Joint Multi-Mission Electro-Optic System (JMMES) Joint Capability Technology Demonstration (JCTD) 2009 Demonstration Execution Document (DED) Assessment Report (Rough)," Naval Postgraduate School Report, 1 December 2009.

**DEPARTMENT OF
OPERATIONS RESEARCH**

**ROBERT F. DELL
CHAIRMAN**

OPERATIONS RESEARCH

OVERVIEW:

The Naval Postgraduate School's operations research (OR) program is a world-class curriculum designed to teach students the science of helping people and organizations make better decisions.

This science is necessary in today's increasingly complex operating environments, in which officers and managers must respond quickly to a vast array of demands, while also weighing the options and consequences of each into their final decisions. Operations research offers a scientific approach to the decision-making process through an array of mathematical, probabilistic, and statistical techniques.

The military uses OR at the strategic, operational, and tactical levels for such activities as national policy analysis, resource allocation, force composition and modernization, logistics, human resources, battle planning, flight operations scheduling, intelligence, command and control, weapon selection, missile defense, engagement tactics, maintenance and replenishment, and search and rescue.

The OR department's mission is:

- To educate analysts who are fully capable of conducting independent, analytical studies of military problems, and have an educational basis for continued learning and development.
- To provide the United States government and its allies with military officers who have a comprehensive knowledge of military operations research, and who can perform and manage quantitative analysis of operational and other defense problems.
- To provide operations research and general analysis support to the Department of Defense (DoD).
- To develop and maintain a world-class research program in operations research and related areas.

CURRICULA SERVED:

The first seven curricula below are homed in the OR Department. Because of OR's broad applications, the Department supports the other curricula with courses ranging from optimization to statistics to human systems integration.

- Operations Analysis
- Operational Logistics
- Human Systems Integration
- Master of Systems Analysis
- Systems Engineering Analysis
- Systems Analysis Certificate
- Human Systems Integration Certificate
- Modeling, Virtual Environments, and Simulation (MOVES)
- Systems Engineering
- Systems Engineering Management/Product Development
- Undersea Warfare
- Information Systems and Operations
- Information Systems Technology
- Information Warfare
- Joint C4I
- Computer Science
- Naval/Mechanical Engineering
- Electronic Warfare
- Applied Mathematics
- Space-Systems Operations International
- Space-Systems Operations
- Manpower Systems Analysis

OPERATIONS RESEARCH

DEGREES GRANTED:

- Master of Science in Operations Research
- Master of Science in Applied Science
- Master of Systems Analysis
- Master of Science in Human Systems Integration
- Doctor of Philosophy in Operations Research

RESEARCH THRUSTS:

- Probability and Stochastic Processes
- Optimization
- Statistics and Data Analysis
- Human Factors and Systems Integration
- Simulation and War Gaming
- Search, Detection, and Evasion

RESEARCH CHAIRS:

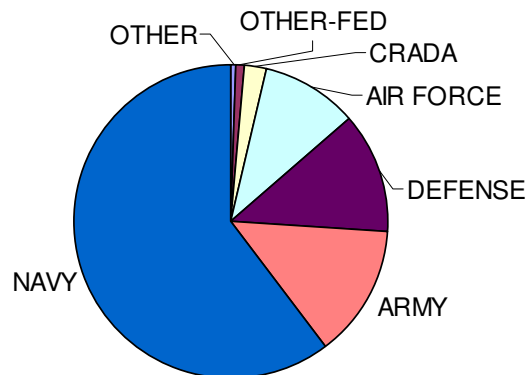
- Chair for Warfare Innovation
- Chair of Applied Systems Analysis

RESEARCH FACILITIES:

- Simulation Lab
- Optimization Lab
- Human Systems Integration Laboratory (HSIL)

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Operations Research is provided below:



Size of Program: \$4.2M

OPERATIONS RESEARCH

Robert F. Dell
Professor and Chair
831-656-2853
dell@nps.edu

R. Kevin Wood
Distinguished Professor and Associate Chair for Research
831-656-2523
kwood@nps.edu

David Alderson
Assistant Professor
831-656-1814
dlalders@nps.edu

James N. Eagle
Professor
831-656-2654
jeagle@nps.edu

Wayne P. Hughes
Professor
831-656-2484
whughes@nps.edu

Jeffrey Appleget
Senior Lecturer
831-656-7674
jaappleget@nps.edu

Lee Ewing
LTC, USA, Military Faculty
831-656-3040
plewing@nps.edu

Patricia A. Jacobs
Professor
831-656-2258
pjacobs@nps.edu

Michael Atkinson
Assistant Professor
831-656-2398
mpatkins@nps.edu

Ronald D. Fricker, Jr.
Associate Professor
831-656-3048
rdfricker@nps.edu

Rachel T. Johnson
Assistant Professor
831-656-2577
rtjohnso@nps.edu

Gordon H. Bradley
Professor
831-656-2359
gbradley@nps.edu

Donald P. Gaver
Distinguished Professor
831-656-2605
dgaver@nps.edu

Quinn Kennedy
Lecturer
831-656-2618
mqkenned@nps.edu

Gerald G. Brown
Distinguished Professor
831-656-2140
gbrown@nps.edu

Thomas E. Halwachs
Senior Lecturer
831-656-2413
halwachs@nps.edu

Jeffrey E. Kline
Senior Lecturer and
Program Director, Maritime
Defense and Security
Research Programs
831-656-7946
jekline@nps.edu

Douglas Burton
CDR, USN, Military Faculty
Applied Systems Analysis
Chair and Lecturer
831-656-2284
drburton@nps.edu

Thomas A. Hamrick
Lecturer
831-656-2590
tahamric@nps.edu

Robert A. Koyak
Associate Professor
831-656-2688
rakoyak@nps.edu

Samuel E. Buttrey
Associate Professor
831-656-3035
buttrey@nps.edu

Alejandro (Andy) Hernandez
COL, USA, Military Faculty
Associate Dean, GSOIS, and
Senior Army Representative
831-656-3116
ahernand@nps.edu

Moshe Kress
Professor
831-656-2927
mkress@nps.edu

W. Matthew Carlyle
Associate Professor
831-656-2106
mcarlyle@nps.edu

Thomas H. Hoivik
Senior Lecturer
831-656-2040
thhoivik@nps.edu

Kyle Y. Lin
Associate Professor
831-656-2648
kylin@nps.edu

Timothy H. Chung
Research Assistant Professor
831-656-7858
thchung@nps.edu

Gary E. Horne
Research Professor
831-233-4905
gehorne@nps.edu

OPERATIONS RESEARCH

Thomas W. Lucas
Associate Professor
831-656-3039
twlucas@nps.edu

Kevin J. Maher
CDR, USN, Military Faculty
831-656-2691
kjmaher@nps.edu

Michael E. McCauley
Research Professor
831-656-2191
memccaul@nps.edu

Mary McDonald
Research Associate
703-634-9024
mlmcdona@nps.edu

David Meyer
LCDR, USN
Military Faculty
831-656-3647
dwmeyer@nps.edu

Nita Lewis Miller
Associate Professor
831-656-2281
nlmiller@nps.edu

Gregory K. Mislick
Lecturer
831-656-3113
gkmislic@nps.edu

Gordon R. Nakagawa
Lecturer Emeritus
831-656-2303
gnakagawa@nps.edu

Scott Nestler
LTC, USA, Military Faculty
Assistant Professor
831-656-7700
stneste@nps.edu

Daniel A. Nussbaum
Visiting Professor
831-656-2387
dnussbaum@nps.edu

Paul O'Connor
Assistant Professor
831-656-3864
peoconno@nps.edu

CAPT Douglas Otte, USN
Chair, Warfare Innovation
831-656-3890
deotte@nps.edu

Steven E. Pilnick
Research Associate Professor
831-656-2283
spilnick@nps.edu

Sergio Posadas
LtCol, USMC
Military Faculty
831-656-7626
sposada1@nps.edu

Wilson Price
Visiting Professor
831-656-2113
wlprice@nps.edu

Peter Purdue
Professor and
Dean of GSOIS
831-656-2663
ppurdue@nps.edu

Robert R. Read
Professor Emeritus
831-656-2382
rread@nps.edu

Anton A. Rowe
Research Associate
415-577-2385
arowe@nps.edu

Johannes O. Royset
Assistant Professor
831-656-2578
joroyset@nps.edu

Javier Salmerón
Associate Professor
831-656-2779
jsalmero@nps.edu

Paul J. Sanchez
Senior Lecturer
831-656-3053
pisanche@nps.edu

Susan M. Sanchez
Professor
831-656-2780
ssanchez@nps.edu

David Schiffman
CDR, USN, Military Faculty
831-656-2380
dlshiff@nps.edu

David Schrady
Distinguished Professor
Emeritus
831-656-2801
dschrady@nps.edu

Lawrence G. Shattuck
Senior Lecturer
831-656-2473
lgshattu@nps.edu

Robert Shearer
LTC, USA, Military Faculty
Assistant Professor
831-656-3027
rlsheare@nps.edu

Roberto Szechtman
Associate Professor
831-656-3311
rszechtm@nps.edu

Alan R. Washburn
Distinguished Professor
Emeritus
831-656-3127
awashburn@nps.edu

Lyn Whitaker
Associate Professor
Operations Research
831-656-3482
lwhitaker@nps.edu

OPERATIONS RESEARCH

NEXT-GENERATION NETWORK SCIENCE

David Alderson, Assistant Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: Net-centric technology promises unprecedented levels of performance and robust efficiency, yet there remains substantial confusion regarding obstacles to achieving this vision. This proposed program will clarify and address the central research challenges: understanding network structure and function, domain-specific drivers and constraints, and the crucial issue of network architecture. Networks must shift from only sensing and communication to real-time, dynamic decision and control with algorithms that are primarily local yet achieve provably global results, all while avoiding the rare but catastrophic real-world failures that are hard to anticipate with simulation-based methods. This “robust yet fragile” feature must be faced by any scalable methodology. This also requires an unprecedented level of mathematical rigor throughout. In collaboration with team members at the University of Pennsylvania, Caltech, UCSB, and UCSD, a broad-based, cross-disciplinary research program is proposed, focused on rigor, scalability, and provability.

THE IRREGULAR WARFARE METHODS AND TOOLS TACTICAL VALIDATION, VERIFICATION, AND ACCREDITATION PROJECT

Jeffrey Appleget, Senior Lecturer
Department of Operations Research
Sponsor: OSD-CAPE, through TRAC-Monterey

OBJECTIVE: To develop a verification, validation, and accreditation (VV&A) best-practices guide (BPG) for irregular warfare (IW) methods, models, and tools (MMT) tactical-level representation; and to apply those best practices to selected existing IW MMT. The peace-support operations model (PSOM) and the cultural geography (CG) model will be assessed since those models are already hosted at the Naval Postgraduate School (NPS) and/or TRAC-Monterey.

SUMMARY: Department of Defense training, experimentation, testing, and analytic communities will require IW MMT to address key issues and requirements. Assessing the utility of IW MMT for selected applications requires different methods, techniques, and standards than have been used to VV&A physics-based combat M&S. In order to properly represent the IW environment, the interactions of combatants with the indigenous population must be represented and assessed, requiring the involvement of cultural, behavioral, and other social scientists, as well as irregular warfare subject matter experts. The principal investigators (PIs) have developed an IW VV&A best-practices guide (in draft form at year’s end, this project concludes in April 2010). Key findings include placing emphasis on model developers clearly identifying the conceptual model, referent, and data required as a precondition for validation. A successful IPR was held with the OSD-CAPE sponsor in November, with a follow-on IPR scheduled in February 2010 to review the BPG draft and evaluate a proposal for follow-on FY10 research. Work continues on assessing PSOM and CG.

A STRATEGIC SOURCING INITIATIVE FOR SERVICES AT AIR FORCE INSTALLATIONS

Aruna Apte, Assistant Professor
Rene Rendon, Associate Professor
Graduate School of Business and Public Policy
Javier Salmerón, Associate Professor
Department of Operations Research
Sponsor: Naval Postgraduate School Acquisition Research Program

OBJECTIVE: To develop a pricing optimization model that can be used in optimal bidding approaches, where multiple offerors propose at multiple installations.

SUMMARY: The U.S. Department of Defense (DoD) annually procures billions of dollars worth of systems, supplies, and services in support of the national military strategy. Faced with budget cuts and other resource constraints, the DoD must monitor its procurement process to ensure a continuous flow of critical supplies and services. One aspect of current transformation in the DoD is the use of a strategic sourcing approach for the procurement of installation-level services. Using the Air Force's strategic sourcing process as the context, an optimization model for selecting a set of bids among multiple offerors' proposals for installation services was developed. The selection achieved the most favorable objective based on balancing the confidence performance level in past performance of the offerors and the cost to the Air Force. The research findings, based on a realistic scenario, demonstrate improvements in both overall performance and cost over the current process.

TECHNICAL REPORT:

Apte, A., Rendon, R., and Salmerón, J., "Sourcing in the Air Force: An Optimization Approach," Naval Postgraduate School Technical Report, NPS-LM-09-131, 2009.

KEYWORDS: Contract Management, Strategic Sourcing, Optimization, Set Covering Problem

**AN OVERLAPPING NETWORKS APPROACH TO RESOURCE ALLOCATION FOR
DOMESTIC COUNTERTERRORISM**

Michael Atkinson, Assistant Professor

Department of Operations Research

Larry Wein, Professor

Stanford University

Sponsor: Naval Postgraduate School (RIP-Borza)

OBJECTIVE: To formulate a mathematical model to evaluate the connections between crime and terror; and determine how and if interdiction efforts can take advantage of those connections.

SUMMARY: Motivated by the links between terror and crime and the difficulty in directly detecting terror activity, the principal investigators (PIs) formulated and solved an optimization problem on overlapping networks to determine how the government should allocate resources to detect terrorists through their criminal connections. The government, knowing only the general structure and overlap of the networks, allocates its scarce resources to investigate each terror and criminal network. There are two stages to the investigation: an initial investigation of all nodes (i.e., terrorists or criminals) and a secondary investigation of criminals identified during the initial investigation to determine if they are terrorists. Applying this model to data derived from a population of terrorists in the United States between 1971-2003 suggests that the government may be able to exploit the terror connections of crimes that are relatively uncommon, somewhat easy to detect, and attractive to terrorists.

PUBLICATION:

Atkinson, M.P. and Wein, L.M., "An Overlapping Networks Approach to Resource Allocation for Domestic Counterterrorism," *Studies of Conflict and Terrorism* (submitted).

PRESENTATIONS:

Atkinson, M.P. and Wein, L.M., "An Overlapping Networks Approach to Resource Allocation for Domestic Counterterrorism," INFORMS Annual Meeting, San Diego, California, October 2009.

Atkinson, M.P. and Wein, L.M., "An Overlapping Networks Approach to Resource Allocation for Domestic Counterterrorism," Risk Symposium, Santa Fe, New Mexico, April 2009.

KEYWORDS: Networks, Counterterrorism, Resource Allocation

OPERATIONS RESEARCH

COUNTER-IMPROVISED, EXPLOSIVE DEVICE RESEARCH

Gordon H. Bradley, Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To conduct research on countering improvised explosive devices (IEDs).

SUMMARY: Research on the effectiveness of route clearance operations and UAV surveillance has been completed. Ongoing research continues on statistical analysis of route clearance operations, the effectiveness of using UAVs to identify IEDs, preventing IED terror campaigns in the United States, and constructing complex adaptive systems based on living systems to model insurgencies and their IED systems.

IMPROVISED EXPLOSIVE DEVICES – RESEARCH AND EDUCATION

Gordon H. Bradley, Professor
Robert A. Koyak, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To support research and education on countering improvised explosive devices (IEDs). Statistical models for point processes focusing on IED emplacements will be developed, along with algorithms for their implementation on data. The Naval Postgraduate School (NPS) SIGACTS Viewer will be used for other analysis. This research supports a graduate seminar on IEDs, with particular focus on countering the networks that support the insurgents.

SUMMARY: This research effort refined the statistical models developed by the investigator (Koyak) for emplacement of IEDs on road networks. Unlike most models currently in use, emplacement models recognize the observable process of IED discoveries as censored events that depend on vehicular movements. The Naval Postgraduate School SIGACTS Viewer was augmented (Bradley) to support counter-IED analysis. The Viewer was further modified to provide search for given words and phrases in the description of IED events to support detailed analysis of IED incidents in Iraq. The improvised explosive devices seminar was offered during the 2009 winter quarter.

SOFTWARE:

Naval Postgraduate School SIGACTS Viewer

TECHNICAL REPORT:

Koyak, R., “Risk on Roads: A Modeling Approach. Part I: Estimation Models,” 2009 (revised March 2009).

KEYWORDS: Improvised Explosive Devices, Point Processes, Censoring

LARGE-SCALE OPTIMIZATION

Gordon H. Bradley, Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To provide continued support of research in large-scale optimization, including the development and implementation of a Global Benders Decomposition Algorithm for solving max-min interdiction models, with an emphasis on electric power-grid models and the Naval Postgraduate School SIGACTS viewer to dynamically display and analyze incident data from *Operation Iraqi Freedom*, and further develop the Network and Graph Markup Language.

OPERATIONS RESEARCH

LARGE-SCALE OPTIMIZATION
Gordon H. Bradley, Professor
Gerald G. Brown, Distinguished Professor
R. Kevin Wood, Distinguished Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To provide continued support of research in large-scale optimization, including development and implementation of a) defender-attacker-defender models, with application to antisubmarine warfare and homeland defense, and b) the Naval Postgraduate School (NPS) SIGACTS Viewer to dynamically display and analyze incident data from *Operation Iraqi Freedom*, and the Network and Graph Markup Language (NaGML).

SUMMARY: Described and implemented a variant on a defender-attacker-defender model for optimal assignments of antisubmarine assets around a “high-value unit,” and continued development of the NPS SIGACTS Viewer, including keyword search capabilities and enhanced filters for IED incidents.

PUBLICATIONS:

Brown, G., Carlyle, M., Harney, R., Skroch, E., and Wood, K., “Interdicting a Nuclear Weapons Project,” *Operations Research*, 57, pp. 866-877, 2009.

Royset, J.O., Carlyle, W.M., and Wood, R.K., “Routing Military Aircraft with a Constrained Shortest-Path Algorithm,” *Military Operations Research*, 14(3), pp. 31-52, 2009.

Salmerón, J., Wood, K., and Baldick, R., “Worst-Case Interdiction Analysis of Large-Scale Electric Power Grids,” *IEEE Transactions on Power Systems*, 24, pp. 96-104, 2009.

Salmerón, J., Wood, R.K., and Morton, D.P., “A Stochastic Program for Optimizing Military Sealift Subject to Attack,” *Military Operations Research*, 14(2), pp. 19-39, 2009.

Singh, K., Philpott, A., and Wood, K., “Dantzig-Wolfe Decomposition for Solving Multi-Stage Stochastic Capacity-Planning Problems,” *Operations Research*, 57, pp. 1271-1286, 2009.

PRESENTATIONS:

Alderson, D., Brown, G., and Carlyle, M., “Rethinking Risk Assessment and Management for Homeland Security and Defense,” American Statistical Association Joint Statistical Meetings, Washington, D.C., 1-6 August 2009.

Brown, G., “How to Assess the Value of Critical Infrastructure: A Worst-Case View of Risk and Its Implications for Defensive Investment,” INFORMS Roundtable, San Antonio, Texas, 10 February 2009.

Brown, G., Price, W., and McCall, V., “Design and Optimal Prepositioning of Humanitarian Assistance Pack-Up Kits to Support Pacific Command Emergency Relief Operations,” INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

Cullenbine, C., Newman, A., and Wood, K., “Optimal Diversion Planning and Protection in Infrastructure Networks,” INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

Salmerón, J., Baldick, R., and Wood, K., “Worst-Case Interdiction, and Defense, of Large-Scale Electric Power Grids,” 20th International Symposium on Mathematical Programming, Chicago, Illinois, 23-28 August 2009.

Wood, K. and Salmerón, J., “U.S. Power Grids: Evaluating and Mitigating Vulnerability to Terrorist Attack,” INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

OPERATIONS RESEARCH

THESES DIRECTED:

Bencomo, L.A., “Modeling the Effects of a Transportation Security Incident on the Commercial Transportation System,” Master’s Thesis, Naval Postgraduate School, September 2009.

Hallmann, F., “Optimizing Operational and Logistical Planning in a Theater of Operations,” Master’s Thesis, Naval Postgraduate School, June 2009.

Li, P.-C., “Planning the Optimal Transit for a Ship through a Mapped Minefield,” Master’s Thesis, Naval Postgraduate School, September 2009.

Pfeiff, D.M., “Optimizing Employment of Search Platforms to Counter Self-Propelled Semi-Submersibles,” Master’s Thesis, Naval Postgraduate School, June 2009.

Scherer, S.D., “Game-Theoretic Anti-Submarine Warfare Mission Planner,” Master’s Thesis, Naval Postgraduate School, September 2009.

Wray, J.D., “Optimizing Helicopter Assault Support in a High Demand Environment,” Master’s Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Integer Programming, Stochastic Programming, Bilevel Programming, Dynamic Planning, Network Optimization, Network Interdiction, Improvised Explosive Devices

LARGE-SCALE OPTIMIZATION
Gerald G. Brown, Distinguished Professor
R. Kevin Wood, Professor
Department of Operations Research
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: This annual proposal for continued support of research in large-scale optimization describes the formulation of defender-attacker-defender models and proposes algorithms for their solution. These models are three-stage Stackelberg games with applications to military-defense problems, critical infrastructure protection, and bio-defense.

SUMMARY: The principal investigators (PIs) have described a three-stage Stackelberg game for optimal hardening of critical infrastructure and other applications: a) the *defender* of a system uses limited resources to harden certain system components, i.e., to make those components resistant or invulnerable to attack, b) an *attacker* observes these defensive preparations and “interdicts” some components, reducing their usefulness to the defender, and c) the defender, as system operator, operates the interdicted system optimally. Typically, system operation is modeled as a linear program. The defender’s overarching goal is to minimize the worst possible damage that the attacker can inflict, when measured through the cost of post-interdiction system operation. This paradigm was applied to bio-defense, using a compartmental epidemiological model to represent “system operation”: this is not a linear program.

PUBLICATIONS:

Alderson, D., Brown, G., and Carlyle, M., “How to Assess the Value of Critical Infrastructure: A Worst-Case View of Risk and its Implications for Defensive Investment,” 2009 (in review).

Brown, G., Carlyle, M., Abdul-Ghaffar, A., and Kline, J., “A Defender-Attacker Optimization of Port Radar Surveillance,” *Naval Research Logistics*, 2009 (to appear).

Brown, G., Carlyle, M., Harney, R., Skroch, E., and Wood, K., “Interdicting a Nuclear Weapons Project,” *Operations Research*, 57, pp. 866-877, 2009.

Newman, A., Rosenthal, R., Salmerón, J., Brown, G., Price, W., and Rowe, A., "Optimizing Assignment of Tomahawk Cruise Missile Missions to Firing Units," *Naval Research Logistics*, 2009 (to appear).

Royset, J.O., Carlyle, W.M., and Wood, R.K., "Routing Military Aircraft with a Constrained Shortest-Path Algorithm," *Military Operations Research*, 14(3), pp. 31-52, 2009.

Salmerón, J., Wood, K., and Baldick, R., "Worst-Case Interdiction Analysis of Large-Scale Electric Power Grids," *IEEE Transactions on Power Systems*, 24, pp. 96-104, 2009.

Salmerón, J., Wood, R.K., and Morton, D.P., "A Stochastic Program for Optimizing Military Sealift Subject to Attack," *Military Operations Research*, 14(2), pp. 19-39, 2009.

Singh, K., Philpott, A., and Wood, K., "Dantzig-Wolfe Decomposition for Solving Multi-Stage Stochastic Capacity-Planning Problems," *Operations Research*, 57, pp. 1271-1286, 2009.

PRESENTATIONS:

Alderson, D., Brown, G., and Carlyle, M., "Rethinking Risk Assessment and Management for Homeland Security and Defense," American Statistical Association Joint Statistical Meetings, Washington, D.C., 1-6 August 2009.

Brown, G., "How to Assess the Value of Critical Infrastructure: A Worst-Case View of Risk and Its Implications for Defensive Investment," INFORMS Roundtable, San Antonio, Texas, 10 February 2009.

Brown, G., Price, W., and McCall, V., "Design and Optimal Prepositioning of Humanitarian Assistance Pack-Up Kits to Support Pacific Command Emergency Relief Operations," INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

Cullenbine, C., Newman, A., and Wood, K., "Optimal Diversion Planning and Protection in Infrastructure Networks," INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

Salmerón, J., Baldick, R., and Wood, K., "Worst-Case Interdiction, and Defense, of Large-Scale Electric Power Grids," 20th International Symposium on Mathematical Programming, Chicago, Illinois, 23-28 August 2009.

Wood, K. and Salmerón, J., "U.S. Power Grids: Evaluating and Mitigating Vulnerability to Terrorist Attack," INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

THESES DIRECTED:

Bencomo, L.A., "Modeling the Effects of a Transportation Security Incident on the Commercial Transportation System," Master's Thesis, Naval Postgraduate School, September 2009.

Hallmann, F., "Optimizing Operational and Logistical Planning in a Theater of Operations," Master's Thesis, Naval Postgraduate School, June 2009.

Li, P.-C., "Planning the Optimal Transit for a Ship through a Mapped Minefield," Master's Thesis, Naval Postgraduate School, September 2009.

Pfeiff, D.M., "Optimizing Employment of Search Platforms to Counter Self-Propelled Semi-Submersibles," Master's Thesis, Naval Postgraduate School, June 2009.

Scherer, S.D., "Game-Theoretic Anti-Submarine Warfare Mission Planner," Master's Thesis, Naval Postgraduate School, September 2009.

OPERATIONS RESEARCH

Wray, J.D., “Optimizing Helicopter Assault Support in a High Demand Environment,” Master’s Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Integer Programming, Stochastic Programming, Bilevel Programming, Dynamic Planning, Network Optimization, Network Interdiction

OPTIMIZATION AND DISCRETE MATHEMATICS

Gerald G. Brown, Distinguished Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To provide continued support of research in large-scale optimization, including the formulation of defender-attacker-defender models and algorithms for their solution. These models are three-stage Stackelberg games with applications to military-defense problems, critical infrastructure protection, and bio-defense.

CHAIR, APPLIED SYSTEMS ANALYSIS

CDR Douglas R. Burton, Chair

Daniel A. Nussbaum, Professor

LCDR Robert M. Corley, Student

Department of Operations Research

Sponsor: OPNAV N81

OBJECTIVE: To explore the fully burdened cost of fuel for the Navy.

SUMMARY: This thesis motivates and defines the concept of fully burdened cost of fuel (FBCF), assesses Department of the Navy major defense acquisition programs potentially impacted by FBCF estimates, and applies an experimental methodology developed by OUSD (AT&L) to estimate and analyze the FBCF of a notional capability. The analysis showed that there are potentially large variations in energy-related costs (burdens) associated with the required fuel delivery assets, the supporting infrastructure and associated manpower, and the assets providing force protection and security to the fuel delivery assets in both peacetime and operational scenarios. Recommendations for follow-on studies are provided.

THESIS DIRECTED:

Corley, R., “Evaluating the Impact of the Fully Burdened Cost of Fuel,” Naval Postgraduate School Thesis, September 2009.

KEYWORDS: FBCF, Fuel Costs, Defense Acquisition

ATTACKING PARALLEL QUEUES

W. Matthew Carlyle, Associate Professor

Roberto Szechtman, Assistant Professor

Department of Operations Research

Shane Henderson, Professor

Cornell University

Sponsor: GEE

OBJECTIVE: To model decision problems where a centralized planner, also known as the *defender*, wishes to design parallel service channels (queues) with the knowledge that an *attacker* (representing worst-case disruptions, either intentional or otherwise) will attempt, in a single attack, to maximize disruption to the system.

OPERATIONS RESEARCH

SUMMARY: Models were developed that shed insight into how to design systems that enjoy economies of scale in their operating costs, when those systems will subsequently face disruptions from accidents, acts of nature, or an intentional attack from a well-informed attacker. The systems were modeled as parallel $M/M/1$ queues, and the key question was how to allocate service capacity among the queues to make the system resilient to worst-case disruptions. This problem was formulated as a three-level sequential game between a defender and a hypothetical attacker.

PUBLICATION:

Carlyle, W.M., Henderson, S.G., and Szechtman, R., "Attacking Parallel Queues," *Naval Research Logistics* (under revision).

KEYWORDS: Defender-Attacker-Defender Problems, $M/M/1$ Queue, Tri-Level Games

MILITARY APPLICATIONS OF OPTIMIZATION

W. Matthew Carlyle, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: Research topics and decision-tool development efforts include the optimal daily assignment of U.S. Navy ships to missions, rapid near-optimal re-tasking of air-strike assets to time-sensitive targets, optimal sensor and munitions package selection and mission assignment, optimizing roadblock and sensor positioning to locate and capture fleeing nuclear-materials smugglers in a road network, and vulnerability analysis and robust design of ISP networks.

MILITARY APPLICATIONS OF OPTIMIZATION

W. Matthew Carlyle, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: Research topics and decision-tool development efforts include the optimal daily assignment of U.S. Navy ships to missions, loadout and routing of unmanned aircraft systems, computer and communication network optimization and interdiction, and optimizing roadblock and sensor positioning to locate and capture fleeing nuclear-materials smugglers.

SEALIFT CAPABILITY: SIZE, COMPOSITION, AND EMPLOYMENT

W. Matthew Carlyle, Associate Professor
Department of Operations Research
Sponsor: Naval Surface Warfare Center-Carver Division

OBJECTIVE: To extend and improve an optimization-based decision-support system for sealift capability assessment to address seabasing, Combat Logistics Force (CLF) Fleet restructuring, CLF ship replacement, assessment of new, high-speed logistics-ship designs, and other analyses.

OPERATIONS RESEARCH

OPTIMIZATION OF SENSOR ALLOCATION FOR SEARCH AND SURVEILLANCE IN MARITIME, LITTORAL, AND URBAN ENVIRONMENTS

Timothy H. Chung, Research Assistant Professor

Moshe Kress, Professor

Johannes O. Royset, Assistant Professor

Department of Operations Research

Sponsor: Office of Naval Research

OBJECTIVE: To develop an operational and tactical decision aid for employing sensors in an area of interest and fusing the information obtained from these sensors and from other sources. The decision aid will consist of two parts: a probability model for fusing information and an optimization model for operating the sensors.

SUMMARY: The decision aid will be used to guide commanders and executive officers to efficiently operate sensors during surveillance missions and to effectively utilize the information obtained from these sensors. The decision aid will also help combat planners in developing concepts of operations for search and surveillance operations and will support analysts in planning acquisition programs for sensors and platforms. The focus was on sensors carried by unmanned aerial, ground, and surface vehicles, but information from ground sensors, satellites, manned aircraft, and human intelligence sources was also considered.

PUBLICATIONS:

Chung, T., Johnson, R., Kress, M., and Royset, J., "Real-Time Optimization of Probabilistic Search, Identification, and Interception for Situational Awareness," (in preparation).

Kress, M., Royset, J., and Rozen, N., "Sensor-Interceptor Operational Policy Optimization for Maritime Interdiction Missions," (in preparation).

CONFERENCE PUBLICATION:

Chung, T., Kress, M., and Royset, J., "Probabilistic Search Optimization and Mission Assignment for Heterogeneous Autonomous Agents," *Proceedings of the International Conference on Robotics and Automation* (to appear).

THESES DIRECTED:

Rozen, N., "Sensor-Interceptor Operational Policy Optimization for Maritime Interdiction Missions," Master's Thesis, Naval Postgraduate School, December 2009.

See, M.A.E., "How to Detect the Location and Time of a Covert Chemical Attack: A Bayesian Approach," Master's Thesis, Naval Postgraduate School, December 2009.

CHAIR, APPLIED SYSTEMS ANALYSIS

Robert F. Dell, Professor

Department of Operations Research

Sponsor: Chief of Naval Operations

OBJECTIVE: To continue support for the Chair of Applied Systems Analysis at the Naval Postgraduate School and to define the activities to be undertaken by the chair.

OPERATIONS RESEARCH

BASE REALIGNMENT AND CLOSURE INFRASTRUCTURE ANALYSIS

Robert F. Dell, Professor

Department of Operations Research

Sponsor: Assistant Chief of Staff for Installation Management

OBJECTIVE: To provide continuing research support and development of optimization models for the Army Assistant Chief of Staff for Installation Management. In the short term, the proposed research focuses on the BAEC Optimization Model developed by the investigator and the Army.

IATF SOCIAL-NETWORK FUNCTIONAL ANALYSIS

LTC Lee Ewing, USA, Military Faculty and Assistant Professor

Department of Operations Research

Sponsor: U.S. Special Operations Command

OBJECTIVE: To research and develop appropriate optimization tools, and to use the analytical tools to assist the Chief of the United States Special Operations Command's Interagency Task Force (USSCOM IATF) in the fulfillment of the division's mission. This research will focus on: 1) providing USSCOM IATF with optimal interdiction analysis of personnel and equipment moving from one location to another; 2) the study of functional networks and the development of models to efficiently analyze these functional networks; 3) researching the social network analysis built upon functional network development and analysis; 4) providing support for student experience tours and theses, which will enable the Naval Postgraduate School Department of Operations Research to continue to refine the functional details essential for correct specification of the underlying social networks; and 5) providing continued reach-back support for the IATF staff.

WAD OPTIMIZATION SUPPORT

LTC Lee Ewing, USA, Military Faculty and Assistant Professor

Department of Operations Research

Sponsor: Army Deputy Chief of Staff, G8

OBJECTIVE: To provide study and support of analytical tools to assist the Chief of the Army 0-8 Force Development Directorate's Warfighting Analysis Division (DAPR-FDA) in the fulfillment of the division's mission. This research will focus on: 1) supporting DAPR-FDA development of optimization models that examine how to distribute equipment inside the budget years in order to maximize equipment readiness across the force; 2) supporting DAPR-FDA development of optimization models that aid in the analysis of alternative EE PEO POM investment strategies to satisfy multiple objectives, e.g., funding the development and procurement of capabilities in terms of enhancing the Army's proficiency, sufficiency, and expectancy; 3) providing support for student experience tours, which will enable the Naval Postgraduate School (NPS) to continue to refine existing optimization models once developed by the NPS Department of Operations Research faculty and DAPR-FDA staff; and 4) providing continued reach-back support for the Analysis Division staff so they become integral players in the continued development of the models and resulting analysis once prototype-model development ends.

STATISTICAL MODELS FOR FORECASTING INSURGENT STRIKES WITH APPLICATION TO IMPROVISED EXPLOSIVE DEVICE ATTACKS IN IRAQ

Ronald D. Fricker, Jr., Associate Professor

Department of Operations Research

Sponsor: Office of Naval Research

OBJECTIVE: To develop spatio-temporal models for improvised explosive device (IED) prediction; and to apply the models to real (classified) IED data assembled from the fusion of information from diverse sources.

OPERATIONS RESEARCH

CHARACTERIZING AND ANALYZING REQUIREMENTS FOR INTEGRATED MARITIME DOMAIN PROTECTION

Donald P. Gaver, Distinguished Professor

Patricia A. Jacobs, Professor

Department of Operations Research

Sponsor: Naval Postgraduate School

OBJECTIVE: To evaluate the numbers and types of assets needed to conduct maritime domain assurance and protection.

SUMMARY: Models were developed and exercised to evaluate the numbers and types of assets needed to conduct maritime domain protection.

PUBLICATION:

Gaver, D.P., Jacobs, P.A., and Sato, H., "Assessing Resource Requirements for Maritime Domain Awareness and Protection (Security)," *International Journal of Performability Engineering*, Vol. 5, No. 1, pp. 85-98, January 2009.

PRESENTATIONS:

LeFever, B., "Evaluation of the Maritime Operational Threat Response Forces for the Pacific Coast Theater," DOT Maritime Security.

LeFever, B., "Evaluation of the Maritime Operational Threat Response Forces for the Pacific Coast Theater," Finalist MORS Tisdale Competition.

LeFever, B., "Evaluation of the Maritime Operational Threat Response Forces for the Pacific Coast Theater," OSD Homeland Defense and National Security Affairs.

CONTRIBUTION TO BOOK:

Gaver, D.P., Jacobs, P.A., and Glazebrook, K.D., "Search for a Malevolent Needle in a Benign Haystack," *Game Theoretic Risk Analysis of Security Threats, Chapter 6*, V.M. Bier and M.N. Azaiez (Eds.), International Series in Operations Research and Management Science, Vol. 128, New York: Springer, 2009.

THESIS DIRECTED:

LeFever, B., "Evaluation of the Maritime Operational Threat Response Forces for the Pacific Coast Theater," Master's Thesis, Naval Postgraduate School, March 2009.

KEYWORDS: Maritime Domain Awareness, Deterministic and Stochastic Models, Automatic Information System, AIS, Trusted Agent, Surveillance, Imperfect Classification

OPERATIONS RESEARCH ANALYSIS TO SUPPORT THE ASSESSMENT OF THE SCALABILITY OF SERVICE ORIENTED ARCHITECTURE

Donald P. Gaver, Distinguished Professor

Patricia A. Jacobs, Professor

Department of Operations Research

Sponsor: OPNAV, N61, N6132D

OBJECTIVE: To develop and study analytic and simulation models to assess the scalability of service oriented architecture (SOA) and cloud computing.

OPERATIONS RESEARCH

SUMMARY: Models for the interaction between consumers, producers, and a registry were proposed and studied. Models to assess the stability of cloud computing and to size the computing cloud were developed and studied. Preliminary analysis of response time-data was undertaken.

PRESENTATIONS:

Gaver, D.P. and Jacobs, P.A., "Operational Performance Analysis of SOA and Cloud Computing," VTC Presentation, 30 September 2009.

Gaver, D.P., Jacobs, P.A., and Lewis, W.C., "Operational Performance Analysis of Cloud Computing," INFORMS National Meeting, San Diego, California, October 2009.

WORKING PAPERS:

Gaver, D.P. and Jacobs, P.A., "08-04-09 Remarks on Simulation Output Reported in Email," August 2009 (working paper).

Gaver, D.P. and Jacobs, P.A., "08-14-09 Remarks on Simulation Output Reported in Email," August 2009 (working paper).

Gaver, D.P. and Jacobs, P.A., "A Dynamical Model (Deterministic or 'Fluid') Relating Consumers, Producers, and a Registry," December 2008 (working paper).

Gaver, D.P. and Jacobs, P.A., "Exponential Queuing Model," August 2009 (working paper).

Gaver, D.P. and Jacobs, P.A., "Preliminary Cost Analysis of a Segment of a Service-Oriented Architecture (SOA) Network," December 2008 (working paper).

Gaver, D.P. and Jacobs, P.A., "A Refinement to the Cloud Model," August 2009 (working paper).

Gaver, D.P. and Jacobs, P.A., "Sizing a Computing Cloud," September 2009 (working paper).

Gaver, D.P., Jacobs, P.A., and Huhns, M., "Analysis of Response Time Data," February 2009 (working paper).

Gaver, D.P., Jacobs, P.A., and Lewis, W.C., "Distribution of Path Lengths in OASIS Hierarchical Graphs," July 2009 (working paper).

Gaver, D.P., Jacobs, P.A., and Lewis, W.C., "Interim II Report: Progress to April 30, 2009, Operations Research Analysis to Support the Assessment of the Scalability and Bottleneck Management of Service Oriented Architecture (SOA)," April 2009 (working paper).

Gaver, D.P., Jacobs, P.A., and Lewis, W.C., "Models to Assess the Stability of Cloud Computing," January 2009 (working paper).

Gaver, D.P., Jacobs, P.A., and Lewis, W.C., "A Stochastic Model for Sizing a Computing Cloud," February 2009 (working paper).

Gaver, D.P., Huhns, M., Jacobs, P.A., and Lewis, W.C., "Interim I Report: Models and Preliminary Findings," Project Name: Service Oriented Architecture Scalability, January 2009 (working paper).

REPORT:

Gaver, D.P. and Jacobs, P.A., "Operations Analysis to Support the Assessment of Scalability of and Bottleneck Management of Service Oriented Architecture," Final Report, 30 September 2009.

OPERATIONS RESEARCH

KEYWORDS: Service Oriented Architecture, Queuing, Decision Analysis, Modeling, Cloud Computing

**TRAINING AND RESEARCH SUPPORT FOR DIRECTOR, OPERATIONAL TEST AND
EVALUATION**

Donald P. Gaver, Distinguished Professor

Patricia A. Jacobs, Professor

Department of Operations Research

Sponsor: Director, Operational Test and Evaluation, Naval Postgraduate School

OBJECTIVE: To develop training and reference material and a new methodology for operational testing use emphasizing modeling and simulation.

SUMMARY: Models to study implementation of the policies to improve the reliability of fielded systems were developed and studied.

PUBLICATIONS:

Gaver, D.P. and Jacobs, P.A., "Discussion of the Paper Entitled Reliability Growth Management Metrics and Statistical Methods for Discrete-Use Systems by J.B. Hall, P.M. Ellner, and A. Mosleh," *Technometrics* (to appear).

Gaver, D.P. and Jacobs, P.A., "System Availability," *Wiley Encyclopedia of Operations Research and Management Science*, New York, New York: Wiley (to appear).

CONFERENCE PUBLICATION:

Gaver, D.P., Jacobs, P.A., and Seglie, E.A., "Early Decision Analysis Guiding System Reliability Growth," *25th Annual National Test and Evaluation Conference*, Atlantic City, New Jersey, 2-5 March 2009 (invited paper).

PRESENTATIONS:

Gaver, D.P. and Jacobs, P.A., "Some Operational Research Issues in System Testing," Mechanical Engineering Department Seminar, University of Minnesota, 30 November 2009.

Gaver, D.P., Jacobs, P.A., and Seglie, E.A., "Early Decision Analysis Guiding System Reliability Growth," *25th Annual National Test and Evaluation Conference*, Atlantic City, New Jersey, 2-5 March 2009.

WORKING PAPERS:

Gaver, D.P. and Jacobs, P.A., "Models for Evaluation of Criterion for Reliability Demonstration during SDD," December 2008 (working paper).

Gaver, D.P. and Jacobs, P.A., "Reliability Growth: Models for Operational Analysis," July 2008 (working paper).

Gaver, D.P., Jacobs, P.A., and Seglie, E., "The Economics of a Reliability Demonstration," January 2009 (working paper).

Gaver, D.P., Glazebrook, K.D., Jacobs, P.A., and Seglie, E., "The Power of a Bolton Reliability Demonstration," August 2009 (working paper).

OPERATIONS RESEARCH

TECHNICAL REPORT:

Gaver, D.P., Glazebrook, K.D., Jacobs, P.A., and Seglie, E.A., "Models for Autonomic Logistics/Condition-Based Maintenance and Military System Readiness," Technical Report (in progress).

THESIS DIRECTED:

Koeneman, P.C., "An Analysis of Sensor Effectiveness to Inform a Predictive Maintenance Policy," Master's Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Military Test and Evaluation, Statistical Data Analysis, Decision Analysis, Modeling and Simulation

THE NETCENTRIC SYSTEMS TEST PROGRAM: JOINT-MISSION EFFECTIVENESS SUPPORT USING DATA FARMING

**Gary E. Horne, Research Professor
Department of Operations Research**

Sponsor:

OBJECTIVE: To develop models and data farming techniques to support the testing of mission effectiveness in a variety of joint system-of-system environments and scenarios.

The Naval Postgraduate School's SEED Center for Data Farming Team supported the overall NST need to conduct testing in a complex joint-mission environment across the acquisition life cycle to improve a program manager's ability to deliver joint capabilities to warfighters. For a joint mission environment with many interdependent systems, assessing individual system and system-of-systems (SoS) contributions to joint mission effectiveness becomes extremely challenging. This complex adaptive SoS environment makes it extremely difficult to plan efficient tests using current test methods and capabilities. Cogent planning for the tests of these complex, adaptive systems involves a very tedious, almost impossible, test planning process for determining what and how exactly to test.

In this project, progress was made in both understanding the vast possibility spaces in joint mission environments and representing the cognitive command and control capabilities inherent in joint activity. The principal investigators (PIs) developed a C2-enabled agent-based model to capture C2 structures and also developing design-of-experiments techniques to test what-if questions in a variety of system-of-system environments and scenarios. The PIs demonstrated the usability of the model in conjunction with data farming this past year; based on these results, the technology will be further developed to support the Joint Testing Board at Yuma Proving Grounds. This effort leveraged the strengths of the data farming and design of experiments work within the department.

CONFERENCE PUBLICATIONS:

Horne, G., "NATO NEC C2 Maturity Model," *NATO SAS-065 Task Group* (chaired by David Alberts), Final Products Workshop, September 2009.

Horne, G. (editor and contributor), *The Scythe, Proceedings and Bulletin of the International Data Farming Community*, Workshop 17, Iss. 5, Germany, January 2009.

Horne, G. (editor and contributor), *The Scythe, Proceedings and Bulletin of the International Data Farming Community*, Workshop 18, Iss. 6, Monterey, California, July 2009.

OPERATIONS RESEARCH

THE DESIGN OF A NEW FIGHTING FLEET

**Wayne Hughes, Senior Lecturer
Department of Operations Research
Sponsor: Office of the Secretary of Defense**

OBJECTIVE: To design a sufficient but affordable American fleet suitable for the 21st century, accompanied by the rationale for it.

OPERATIONS RESEARCH ANALYSIS TO SUPPORT THE ASSESSMENT OF THE SCALABILITY OF SERVICE ORIENTED ARCHITECTURE

**Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: Chief of Naval Operations, N61**

OBJECTIVE: Current Navy communication networks consist of many users, servers, routers, switches, and communication lines. Many subsets of users have their own dedicated servers and their own software; i.e., their own clients/server networks. This client/server architecture is expensive to update and maintain. The Department of Defense (DoD) has started investigating implementation of a distributed communication architecture that will support self-connecting networks. One such distributed communication architecture is service-oriented architecture (SOA). The architecture will use a common message protocol to communicate between the different servers, thus allowing different servers to communicate with each other even if their operating systems, etc., are different. The promise is that this type of network architecture will eventually be less expensive to update and maintain, and will also be faster, with greater security and traffic-handling.

REQUIREMENTS AND ASSESSMENTS, OPERATIONS RESEARCH/NETWORK MODELING

**Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: Chief of Naval Operations, N61, N6132D**

OBJECTIVE: To develop and study analytic and simulation models to assess the scalability of a service oriented architecture.

RESEARCH, ANALYTICAL TOOLS, AND TRAINING SUPPORT FOR DOT&E

**Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: Director, Operational Test and Evaluation**

OBJECTIVE: To support and enhance the testing capabilities of the Director, Operational Test and Evaluation (DOT&E). To assist DOT&E in promoting the value of appropriate testing and test result analysis and application. Direction and efforts are to be reviewed and guided by the DOT&E Science Advisor (SA, D). To collaborate with SA, D to enhance and upgrade a paper for acquisition and T&E operational testers and action officers describing the proper and necessary role of T&E in the acquisition and testing process. To continue developing technical tools to assist acquisition executives, DOT&E, and service testers with solving problems of resource allocation to T&E in particular programs. To support and assist the Institute for Defense Analysis in creating an upgraded and updated reliability, availability, and maintainability (RAM) primer. To assist with writing and organizing a technical/statistical addition to the primer. An important topical area for (further) investigation is the operational testing implications of a memorandum authored by Assistant Secretary of the Army (ATL) Bolton. The memorandum requires systems to demonstrate that their mean time between failures (MTBF) is at least a constant times the system's required MTBF during the system development and demonstration (SDD) phase; unless otherwise specified and justified, the constant is 0.7. Models extending the CROW/AMSAA Reliability Growth

OPERATIONS RESEARCH

Model will be used to study issues such as specification of the constant and when the demonstration should take place during SDD to minimize the expected acquisition cost.

STATISTICAL ADVANCEMENTS: EXPERIMENTAL DESIGN AND RISK ANALYSIS

Rachel T. Johnson, Assistant Professor

Department of Operations Research

Sponsor: Naval Postgraduate School

OBJECTIVE: To investigate three main areas of research: 1) the design and analysis of computer experiments; 2) combining data from multiple sources for risk and uncertainty analysis; and 3) optimal designs for nonlinear models.

STATISTICAL ADVANCEMENTS: EXPERIMENTAL DESIGN AND RISK ANALYSIS

Rachel T. Johnson, Assistant Professor

Department of Operations Research

Sponsor: Naval Postgraduate School (Research Initiation Program)

OBJECTIVE: To develop advancements in experimental design and analysis techniques with a focus on military-related applications.

Statistical engineering is a disciplined approach to enable data-driven decisions in the presence of uncertainty, while specifying the risks of mistakes. Two extremely important tools within statistical engineering are the design and analysis of experiments and response surface methodology (RSM). The focus of this research is to develop statistical advancements within both of these tools.

PUBLICATIONS:

Chung, T., Johnson, R., Kress, M., and Royset, J., "Real-Time Optimization of Probabilistic Search, Identification, and Interception for Situational Awareness," *Military Operations Research* (in preparation).

Johnson, R.T. and Montgomery, D.C., "Choice of Second-Order Response Surface Designs for Logistic and Poisson Regression Models," *International Journal of Experimental Design and Process Optimisation*, 1(1), p. 2-23, 2009.

Johnson, R.T. and Montgomery, D.C., "Effect of Bayes Prior Distribution on Optimal Experimental Design Efficiency," *Journal of Quality Technology*, 2009 (in preparation).

Simpson, J., Johnson, R.T., and Montgomery, D.C., "The Design and Analysis of Experiments in the Defense Community," *Military Operations Research*, 2009 (in preparation).

PRESENTATIONS:

Johnson, R.T., "Applied Experiment Design for an Autonomous Search Simulation," INFORMS, San Diego, California, October 2009.

Johnson, R.T., "An Empirical Comparison of Computer Experiments," Quality and Productivity Research Conference, Yorktown Heights, New York, June 2009.

Johnson, R.T., Lampe, T.A., and Seichter, S., "Calibration of an Agent-Based Simulation Model Depicting a Refugee Camp Scenario," Winter Simulation Conference, Austin, Texas, December 2009.

KEYWORDS: Computer Experiments, Optimal Design, Non-Linear Models

OPERATIONS RESEARCH

USING EFFICIENT DESIGN-OF-EXPERIMENTS TO EXPLORE THE ARMY'S EQUIPPING ENTERPRISE SYSTEM

Rachel T. Johnson, Assistant Professor
Department of Operations Research
Sponsor: U.S. Army, G-1

OBJECTIVE: The Army G-1 uses computational models extensively as part of its process for developing, managing, and executing personnel plans, programs, and policies. These models tend to have a large number of inputs with potentially intricate interactions. Furthermore, these are sources of uncertainty associated with many of these inputs, e.g., future reenlistment rates and the elasticities of various bonus options. This project will leverage the benefits of using state-of-the-art experimental design techniques to investigate one or more G-1 models or sub-models. The objectives will include assessing sensitivities, identifying critical input data, quantifying interactions, and generating distributions of future possibilities. The SEED Center will team with the Army G-1, and, if possible, student officers at the Naval Postgraduate School will use efficient high-dimensional design of experiments to investigate agreed upon models.

USING EFFICIENT DESIGN-OF-EXPERIMENTS TO EXPLORE MODELS IN THE ARMY'S PERSONNEL MANAGEMENT SYSTEM

Rachel T. Johnson, Assistant Professor
Susan Sanchez, Professor
Department of Operations Research
Sponsor: Army G-1

OBJECTIVE: To use experimental design techniques to investigate the Enlisted Specialty G-1 Model.

SUMMARY: The Army G-1 uses models extensively as part of its process of developing, managing, and executing personnel plans, programs, and policies. Experimental design and analysis techniques were used to assess sensitivities, identify critical input data, quantifying interactions, and generating distributions of output results from the enlisted specialty model. These efforts provide G-1 with timely insights about model performance and results.

PUBLICATION:

Erdman, R.W., "Enlisted Specialty Model Analysis through Design of Experiments," (in preparation).

KEYWORDS: Experimental Design, Robust Analysis, Manpower Modeling

THE APPLIED PHYSICS LABORATORY EXPERIENCE TOUR

Jeffrey E. Kline, Senior Lecturer
Department of Operations Research
Sponsor: Johns Hopkins University, Applied Physics Laboratory

OBJECTIVE: The Naval Postgraduate School (NPS) and the Johns Hopkins University Applied Physics Laboratory (JHU/APL) have an agreement whereby NPS may provide personnel to support JHU/APL, which also affords the NPS student(s) field experience applicable to their studies.

OPERATIONS RESEARCH

THE DEVELOPMENT OF OPERATIONAL PLANNING TOOLS FOR THE MARITIME OPERATIONS CENTER

Jeffrey E. Kline, Senior Lecturer
Gerald G. Brown, Distinguished Professor
R. Kevin Wood, Distinguished Professor
W. Matthew Carlyle, Associate Professor
Alan R. Washburn, Professor
Javier Salmerón, Associate Professor
Anton A. Rowe, Research Associate
Carol O'Neal, Research Associate
Regina Kaiser, Research Associate
John Looney, Military Faculty Information Science
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To develop and evaluate decision aids for use by Navy staffs to plan maritime operations.

SUMMARY: This research will produce, develop, evaluate, and deliver complete, operational prototypes of various, optimization-based planning systems for supporting the Maritime Operations Center and Maritime Headquarters planning staff in maritime operational missions ranging from strike; information, surveillance, and reconnaissance; theater security and cooperation; theater ballistic missile defense; anti-submarine warfare; logistics routing; transit planning; maritime interdiction operations; and others. In 2009 this program further advanced prototypic decision aids related to maritime operational-level planning. These included models for naval mission planning (Naval Mission Planner), combat logistics force planning (Combat Logistics Force Planner), area anti-submarine warfare planning (ASW Planner), and engagement mission planning from a sea base (GFSMP). The Combat Logistics Force Planner and GFSMP were selected by the Navy Warfare Development Command and Commander, Second Fleet Staff, to be evaluated in a formal set of exercises named Trident Warrior 09. Commander, Second Fleet, personally recognized this research team's contribution to the exercise series. In addition, during 2009, the Naval Underwater Warfare Center requested further development of the ASW Planner for their suite of analytical tools, OPNAV N-4 used the Combat Logistics Force Model in the Navy's QDR, and the Military Sealift Command has requested modification of the Combat Logistics Force Planner as an operational scheduler for the Pacific Fleet.

PUBLICATION:

Salmerón, J., Kline, J., and Spitz, G., "Optimizing Schedules for Maritime Humanitarian Cooperative Engagements from a U.S. Navy Sea Base," *Interfaces*, 2010 (to appear).

CONFERENCE PUBLICATION:

Brown, G., Carlyle, W.M., Kelton, D., Kline, J., and Salmerón, J., "Operational Planning Tools for U.S. Navy Maritime Commanders," *International Conference on Harbor, Maritime, and Multimodal Logistics Modeling and Simulation*, A. Bruzzone, G. Cunha, R. Martínez, and Y. Merkuryev (Eds.), Universidad de La Laguna, Tenerife, Spain, ISBN 978-84-692-5416-5, 2009.

PRESENTATIONS:

Brown, G., Carlyle, W.M., Kelton, D., Kline, J., and Salmerón, J., "Operational Planning Tools for U.S. Navy Maritime Commanders," 6th International Mediterranean Modeling Multiconference – International Conference on Harbor, Maritime, and Multimodal Logistics Modeling and Simulation, Puerto de La Cruz, Spain, 23-25 September 2009.

Kline, J., "Use of Optimization to Create Maritime Operational Planners," Office of Naval Research-sponsored U.S./Chilean Conference on Naval Operations Research, 4 December 2009.

OPERATIONS RESEARCH

THESIS SPONSORED:

Hallman, F., "Optimizing Operational and Logistical Planning in a Theater of Operations," Master's Thesis, Naval Postgraduate School, June 2009.

Pfeiff, D.M., "Optimizing Employment of Search Platforms to Counter Self-Propelled Semi-Submersibles," Master's Thesis, Naval Postgraduate School, June 2009.

Rodman, M.R., "Assessment of a Heuristic Algorithm for Scheduling Theater Security Cooperation Naval Missions," Master's Thesis, Naval Postgraduate School, March 2009.

Scherer, S.D., "Game-Theoretic Anti-Submarine Warfare Mission Planner (Heuristic-Based, Fully Excel Capable)," Master's Thesis, Naval Postgraduate School, September 2009.

Silva, R.A., "Optimizing Multi-Ship, Multi-Mission Operational Planning for the Joint Force Maritime Component Commander," Master's Thesis, Naval Postgraduate School, March 2009.

Wray, J.D., "Optimizing Helicopter Assault Support in a High Demand Environment," Master's Thesis, Naval Postgraduate School, June 2009.

THE MARITIME DEFENSE AND SECURITY RESEARCH MANAGEMENT ACCOUNT

Jeffrey E. Kline, Senior Lecturer
Department of Operations Research
National Security Institute
Sponsor: Naval Postgraduate School Directed Research

OBJECTIVE: To conduct, coordinate, and collaborate maritime defense and security research, experimentation, and information exchange between partnership universities; federal, state, and local agencies; national laboratories; the maritime industry; and international partners through the National Security Institute.

SUMMARY: The Maritime Defense and Security Research program (MDSRP) underwrites several major field experiments at the Naval Postgraduate School (NPS), including the maritime interdiction experimentation by Tactical Network Topology (TNT), COASTS, and SEAWEB. Other programs funded under this umbrella include the GSEAS maritime domain awareness work and environmental impact on sensors research. In 2009, the MDSRP also sponsored the Maritime Information Sharing Task Force (MIST), which, co-sponsored with the Department of Transportation, held symposia at the Port of Everett, Washington, to obtain information on policy barriers to information exchange between commercial entities and government agencies. This research also supports faculty labor and travel to attend various maritime homeland-defense and security conferences or host them at NPS. This project also allows NPS to publish and distribute the monthly SITREP e-newsletter, which reports country-wide research initiatives related to maritime security.

PUBLICATION:

Gaver, D.P., Jacobs, P.A., and Sato, H., "Assessing Resource Requirements for Maritime Domain Awareness and Protection (Security)," *International Journal of Performability Engineering*, Vol. 5, No. 1, pp. 85-98, January 2009.

CONFERENCE PUBLICATIONS:

Ramp, S., Rice, J., Stacey, M., Garfield, T., and Largier, J., "SF Bayweb 2009: Planting the Seeds of an Observing System in the San Francisco Bay," *MTS/IEEE Oceans Conference*, Biloxi, Mississippi, 26-29 October 2009.

OPERATIONS RESEARCH

Rice, J. and Ramp, S., “San Francisco Bayweb 2009,” *ACM SenSys Workshop on Under-Water Networking*, Berkeley, California, 3 November 2009.

PRESENTATIONS:

Kline, J., “Piracy and Maritime Security,” World Affairs Council, San Francisco, California, 18 November 2009.

Kline, J., “Securing the Maritime Global Commons,” U.S. Mission to the United Nations, Geneva, Switzerland, 22 September 2009.

LeFever, B., “Evaluation of the Maritime Operational Threat Response Forces for the Pacific Coast Theater,” DOT Maritime Security, March 2009.

LeFever, B., “Evaluation of the Maritime Operational Threat Response Forces for the Pacific Coast Theater,” MORS Tisdale Competition (finalist), March 2009.

LeFever, B., “Evaluation of the Maritime Operational Threat Response Forces for the Pacific Coast Theater,” OSD (Homeland Defense and National Security Affairs), March 2009.

Ramp, S., Rice, J., Stacey, M., Williams, M., Largier, J., Garfield, T., and Bahr, F., “SF Bayweb 2009, Planting the Seeds of a New Observing System in the San Francisco Bay,” Eastern Pacific Ocean Conference, Victoria, British Columbia, Canada, 23-26 September 2009.

Walsh, W., “Maritime Information Sharing Taskforce: Capturing the Voice of Maritime Industry in Information Sharing,” AIAA Homeland Security Conference, Monterey, California, 3 September 2009.

Walsh, W., “Maritime Information Sharing Taskforce: Capturing the Voice of Maritime Industry in Information Sharing,” Global Maritime Information Sharing Symposium, Washington D.C., 16 September 2009.

CONTRIBUTIONS TO BOOKS:

Gaver, D.P., Jacobs, P.A., and Glazebrook, K.D., “Search for a Malevolent Needle in a Benign Haystack,” *Game Theoretic Risk Analysis of Security Threats, Chapter 6*, V.M. Bier and M.N. Azaiez (Eds.), International Series in Operations Research and Management Science, Vol. 128, New York: Springer, 2009.

Kline, J., “Maritime Security,” *Securing the Global Commons*, S. Jasper (Ed.), Stanford Press, 2010.

WHITE PAPER:

Davidson, K.L., Frederickson, P.A., and Huynh, T.V., “NPS System-of-Systems Exploitation of Knowledge of Atmospheric and Ocean Surface Impacts for MIO and Maritime Security,” White Paper prepared for Commander, Navy Meteorology and Oceanography Command, 9 pp., February 2009.

TECHNICAL REPORT:

Salem, A., Walsh, W., and Englehorn, L., “Industry and Public Sector Cooperation for Information Sharing: Ports of the Puget Sound,” Naval Postgraduate School Technical Report, July 2009.

THESIS DIRECTED:

LeFever, B., “Evaluation of the Maritime Operational Threat Response Forces for the Pacific Coast Theater,” Master’s Thesis, Naval Postgraduate School, March 2009.

OPERATIONS RESEARCH

KEYWORDS: Maritime Security, Maritime Infrastructure

NAVAL OPERATIONS ANALYSIS
Jeffrey E. Kline, Senior Lecturer
Department of Operations Research
Sponsor: Northrop Grumman Shipbuilding, Inc.

OBJECTIVE: In 2008, NGSB stood up a new “Platform Integration and CONOPS” organization that seeks to develop and embed the optical usage of modeling, simulation, and analysis (MS&A) throughout the entire ship-design process in order to reduce risk and control cost. Current platform integration and CONOPS team capabilities include: establishing channels of open communication with both acquisition and service/joint end-user communities; an integrated suite of engineering-level and process models that enable assessment of the ability of platform subsystems to support a worst-case operational demand; and campaign, theater, mission, and engagement-level software tools and the associated development capabilities that enable the simulative study of multiple maritime platforms acting in concert.

NAVAL OPERATIONS ANALYSIS
Jeffrey E. Kline, Senior Lecturer
Department of Operations Research
Sponsor: Northrop Grumman Ship Systems, Inc.

OBJECTIVE: Operations analysis is the development and application of mathematical models, statistical analyses, simulations, analytical reasoning, and common sense to the improvement of real-world operations. Practitioners are called on to advise military and civilian decision-makers on the allocation of scarce resources, the selection of new equipment and processes, and the optimal deployment of given resources to achieve desired goals.

NAVAL OPERATIONS ANALYSIS TO SUPPORT NORTHROP GRUMMAN SHIP SYSTEMS ANALYSIS

Jeffrey E. Kline, Senior Lecturer
Regina Kaiser, Research Associate
Department of Operations Research
Matthew Boensel, Senior Lecturer
Department of Systems Engineering
Sponsor: Northrop Grumman Ship Systems, Inc.

OBJECTIVE: To explore the use of analytical models, systems analysis, and warfare analysis to inform ship design.

SUMMARY: NGSB partnered with the Naval Postgraduate School (NPS) to devise, build, develop, exercise, and assess a new analytical and modeling construct. NPS faculty expertise in independent defense-planning scenario generation, determination of critical performance parameters, and tactical- and mission-level mathematical modeling is considered instrumental to project success. Furthermore, in the course of their NPS curriculum, OA students perform numerous short-term studies, including CONOPS development and concept development and experimentation projects. Students must also complete a research thesis. Many of the joint studies and projects complement both contracted and independent MS&A research and development projects conducted at Northrop Grumman Shipbuilding, and are anticipated to provide innovative and provocative insights into evolving Navy and joint-service mission needs, operating concepts, and analysis methodology. NPS supported Northrop Grumman work in CY09 by creating three defense guidance-like scenarios, generating tactical situations from those scenarios, modeling them in Naval Simulation System, and creating a tactical air-defense model for missile defense.

KEYWORDS: Warfare Analysis, Tactical Analysis, Modeling

OPERATIONS RESEARCH

PREDICTION OF REMAINING USEFUL LIFE IN MECHANICAL COMPONENTS

Robert A. Koyak, Associate Professor
Department of Operations Research
Sponsor: Goodrich Corporation

SUMMARY: Assisted the doctoral research of CDR David Ruth. CDR Ruth's research involved applications to predicting the remaining useful life in helicopter-related mechanical components. It expires in February 2011.

DOCTORAL THESIS:

Ruth, D., "Applications of Assignment Algorithms to Nonparametric Tests for Homogeneity," Doctoral Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: Condition-Based Maintenance, Mechanical Prognostics

STATISTICAL SUPPORT TO THE APACHE BLOCK III TEST PROGRAM

Robert A. Koyak, Associate Professor
Department of Operations Research
Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: To support research and analysis of data from testing the Apache helicopter fire-control radar at the U.S. Army Yuma Test Center.

SUMMARY: Data from 1998 tests of the Apache fire-control radar (FCR) was used to develop a statistical methodology for determining radar detection errors using matching algorithms and a set of identified predictor variables. Computer software (S-Plus) was developed to implement the methodology and was delivered to the sponsor.

THESIS DIRECTED:

Davis, B., "Assessing the Effectiveness of the AH-64D Longbow Apache Helicopter Sensor in the Acquisition of Targets," Master's Thesis, Naval Postgraduate School, June 2009 (Classification: SECRET).

KEYWORDS: Assignment Algorithms, Logistic Regression, Classification Errors

A DYNAMIC MODEL FOR POLITICAL STAKEHOLDERS

Moshe Kress, Professor
Roberto Szechtman, Assistant Professor
Michael Atkinson, Assistant Professor
Department of Operations Research
Sponsor: SOCOM

OBJECTIVE: To develop a dynamic model to capture cause-and-effect relations resulting from actions by stakeholders; and to analyze the impact of external shocks over a time-horizon lasting three to five years. Shocks include the addition or subtraction of stakeholders and dramatic changes in interests, states, preferences, or the ability to form coalitions. Shocks may occur because of assassinations, coup d'états, etc. The model is applied to Lebanon and focuses on Lebanese Hezbollah.

SUMMARY: A social/economic/political situation comprising several stakeholders is considered. The Lebanese Hezbollah and its interactions with other entities are examined; however, this analysis can be applied to other scenarios. The situation evolves over (discrete) time, with the stakeholders taking observable actions at each time step. A Markov decision process is formulated to drive the model dynamics. At each stage, every stakeholder is characterized by a state; each state is associated with a set of

feasible actions that the stakeholder may take. At the end of each stage, depending on the actions taken by all stakeholders, the state of each stakeholder changes.

KEYWORDS: Markov Decision Process, Influence Diagrams, Lebanese Hezbollah

DYNAMICS OF POPULAR ATTITUDES IN COUNTERINSURGENCY SITUATIONS

Moshe Kress, Professor

Roberto Szechtman, Assistant Professor

Michael Atkinson, Assistant Professor

Department of Operations Research

Sponsor: TRADOC/TRAC/TRISA

OBJECTIVE: To develop utility-based models that capture situational awareness and population-behavior effects in counterinsurgency situations.

SUMMARY: A suite of utility-based models that capture the effects of situational awareness, benefits, imposition, and coercion in COIN situations was developed. The resulting mathematical models revealed interesting insights regarding the effects of key state variables in an insurgency situation at steady state. In particular, cascading and tipping point effects were shown.

PUBLICATIONS:

Atkinson, M.P., Kress, M., and Szechtman, R., "When a Bit More is Too Much: The Cascading Effect of Insurgency Actions on Popular Attitudes," (in preparation).

Kress, M. and Szechtman, R., "Why Defeating Insurgencies is Hard: The Effect of Intelligence in Counterinsurgency Operations – A Best Case Scenario," *Operations Research*, V. 57, pp. 578-58, 2009.

PRESENTATIONS:

Atkinson, M.P., Kress, M., and Szechtman, R., "The Effect of Insurgency Actions and Coercion on Popular Attitudes," Human Social Culture Behavior Modeling Program: Focus 2010, Chantilly, Virginia, August 2009.

Atkinson, M.P., Kress, M., and Szechtman, R., "When a Bit More is Too Much: The Cascading Effect of Insurgency Actions on Popular Attitudes," Brief to the Sponsor, TRISA, Ft. Leavenworth, Kansas, June 2009.

Atkinson, M.P., Kress, M., and Szechtman, R., "When a Bit More is Too Much: The Cascading Effect of Insurgency Actions on Popular Attitudes," INFORMS Annual Meeting, October 2009.

Atkinson, M.P., Kress, M., and Szechtman, R., "When a Bit More is Too Much: The Cascading Effect of Insurgency Actions on Popular Attitudes," Joint Workshop of the Turkish and Israeli Operations Research Societies, Istanbul, September 2009.

KEYWORDS: Counterinsurgency, Coercive Actions, Tipping Point, Utility Function

OPERATIONS RESEARCH

THE EFFECT OF INSURGENTS' ACTIONS – A UTILITY THEORY APPROACH

Moshe Kress, Professor

Roberto Szechtman, Assistant Professor

Michael Atkinson, Assistant Professor

Department of Operations Research

Sponsor: TRADOC/TRAC/TRISA

OBJECTIVE: To develop utility-based models that capture situational awareness and population-behavior effects in counterinsurgency situations.

SUMMARY: Utility-based models were developed that capture the effects of situational awareness, benefits, imposition, and coercion in COIN situations. The resulting mathematical models revealed interesting insights regarding the effects of key state variables in an insurgency situation at steady state. In particular, cascading and “tipping point” effects were shown.

PUBLICATIONS:

Atkinson, M.P., Kress, M., and Szechtman, R., “When a Bit More is Too Much: The Cascading Effect of Insurgency Actions on Popular Attitudes,” (in preparation).

Kress, M. and Szechtman, R., “Why Defeating Insurgencies is Hard: The Effect of Intelligence in Counterinsurgency Operations – A Best Case Scenario,” *Operations Research*, V. 57, pp. 578-585, 2009.

PRESENTATIONS:

Atkinson, M.P., Kress, M., and Szechtman, R., “The Effect of Insurgency Actions and Coercion on Popular Attitudes,” Human Social Culture Behavior Modeling Program: Focus 2010, Chantilly, Virginia, August 2009.

Atkinson, M.P., Kress, M., and Szechtman, R., “When a Bit More is Too Much: The Cascading Effect of Insurgency Actions on Popular Attitudes,” INFORMS Annual Meeting, San Diego, California, October 2009.

Atkinson, M.P., Kress, M., and Szechtman, R., “When a Bit More is Too Much: The Cascading Effect of Insurgency Actions on Popular Attitudes,” WITOR-09, Istanbul, September 2009.

KEYWORDS: Counterinsurgency, Coercive Actions, Tipping Point, Utility Function

MODELING THE DYNAMICS OF INSURGENCY AND COUNTERINSURGENCY

Moshe Kress, Professor

Department of Operations Research

Sponsor: U.S. Army Training and Doctrine Command

OBJECTIVE: To develop a suite of models focused at both intangible and tangible (attrition) processes that may help explain cause-and-effect relations in insurgency situations and may be implemented in current or future Army modeling and simulation efforts.

OPERATIONS RESEARCH

MODELING SOCIAL DYNAMICS IN COUNTERINSURGENCY SITUATIONS

Moshe Kress, Professor

Roberto Szechtman, Assistant Professor

Michael Atkinson, Assistant Professor

Department of Operations Research

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To develop a suite of models that capture the dynamics of interactions among groups in a social network, the effect of such interactions on social behavior, and the impact of social behavior on adversarial behavior such as improvised explosive devices (IEDs). The long-term goal is two-fold: a) to develop and study a new family of mathematical models that address the dynamics of popular attitudes in the context of countering insurgencies and terror campaigns, and b) to incorporate the models in an education and training tool.

Key components of the models are attributes (education, available resources, religion, ethnic sect, etc.) and factors (influence from other groups, competition, social comparisons, media influence, etc.) in the context of a “battle for the hearts and minds” of civilian populations. The main objective is to gain cause-and-effect insights that could be translated into effective decision and training tools. Such insights and tools enhance the knowledge-base of U.S. and Coalition forces in dealing with adversarial non-state actors, in particular through better understanding of societal effects of U.S. Force behavior.

PUBLICATIONS:

Atkinson, M.P., Kress, M., and Szechtman, R., “Benefits, Impositions, and Coercion: A Dynamic Model for Population Reaction to Insurgents Actions,” (in preparation).

Kaplan, E., Kress, M., and Szechtman, R., “Confronting Elusive Insurgents,” *Operations Research* (to appear).

PRESENTATION:

Kress, M. and Szechtman, R., “Why Defeating Insurgencies is Hard: The Effect of Intelligence in Counterinsurgency Operations – A Best Case Scenario,” WITOR-09, Istanbul, September 2009.

KEYWORDS: Counterinsurgency, Difference Equations, Coercion

OPTIMIZATION OF SENSOR ALLOCATION FOR SEARCH AND SURVEILLANCE IN MARITIME, LITTORAL, AND URBAN ENVIRONMENTS

Moshe Kress, Professor

Department of Operations Research

Sponsor: Office of Naval Research

OBJECTIVE: To develop an operational and tactical decision aid for selecting sensors and platforms for search and surveillance operations in a theater, allocating the selected sensors to specific missions in the theater, operating the allocated sensors during a mission, and fusing information from the sensors and other sources.

OPERATIONS RESEARCH

OPTIMIZATION OF SENSOR OPERATION FOR SEARCH, SURVEILLANCE, AND RAPID, ACCURATE DECISION-MAKING IN MARITIME, LITTORAL, AND URBAN ENVIRONMENTS

Moshe Kress, Professor

Department of Operations Research

Sponsor: Office of Naval Research

OBJECTIVE: To develop a unified tactical decision aid for 1) operating mobile sensors during search and surveillance missions; and 2) fusing information from the sensors and other sources and obtaining meaningful, updated, and accurate situational-awareness pictures. The decision aid will consist of an optimization model for operating sensors and platforms; standard and specialized algorithms for efficiently solving the model; and Bayesian probability models for fusing information, updating situational awareness, and revising input data.

RESOURCE ALLOCATION IN AN ARMS RACE

Moshe Kress, Professor

Department of Operations Research

B. Golany, Professor

M. Penn, Associate Professor

U. Rothblum, Professor

Technion, Israel

Sponsor: Office of Naval Research (partially)

OBJECTIVE: To develop optimization models for resource allocation for research and development projects of weapons' countermeasures.

SUMMARY: The principal investigators (PIs) considered an arms race between two sides: Red (R) and Blue (B). The focus was on the *tactical* level, where the two sides race, one against the other, in developing weapons of tactical scale. The winner of the race has a temporary advantage until the other side completes the development and deploys its weapon, which neutralizes the effect of the winner's weapon. The PIs studied an asymmetric situation where R is the *attacker* and B is the *defender*, who attempts to counter the attacker's new weapons. The problem was to allocate resources such that costs, time, and effectiveness were traded off optimally.

PUBLICATIONS:

Golany, B., Kress, M., Penn, M., and Rothblum, U., "Network Optimization Models for Resource Allocation in Developing Military Counter Measures," *Operations Research* (under review).

Golany, B., Kress, M., Penn, M., and Rothblum, U., "Resource Allocation in a Tactical Arms Race with Temporary Advantages," *NRL* (under review).

PRESENTATION:

Golany, B., Kress, M., Penn, M., and Rothblum, U., "Resource Allocation in a Tactical Arms Race with Temporary Advantages," INFORMS Annual Meeting, San Diego, California, October 2009.

OPERATIONS RESEARCH

ASSEMBLY OF SEA BASE ASSETS FROM GLOBALLY DISPERSED LOCATIONS

Kyle Y. Lin, Associate Professor
Department of Operations Research
Sponsor: Chief of Naval Operations

OBJECTIVE: To develop two mathematical models for the assembly of sea base assets from globally dispersed locations. Both models will allow flexible inputs and produce optimal solutions to meet certain mission requirements.

EXTENSIONS TO GAME-THEORETIC MODELS FOR JAMMING RCIEDS AND RED TEAMING

Kyle Y. Lin, Associate Professor
Department of Operations Research
Yu-Chu Shen, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: A radio-controlled improvised explosive device (RCIED) has been a major weapon of choice by the insurgents in *Operation Iraqi Freedom* since 2003. One effective way to prevent an RCIED attack is to use electronic jamming devices to interfere with the communication between the trigger and the bomb itself. Due to power constraints, however, a jammer usually cannot jam all triggers simultaneously. This project uses game-theoretic models to develop strategies on how to use electronic jamming devices most effectively against RCIEDs.

SUMMARY: This project used game-theoretic models to study both active jamming and reactive jamming. In both cases, the optimal jamming strategy involved randomizing the jamming loadsets according to an optimal probability distribution. This optimal mixed strategy can be computed by linear programming for active jamming, and by an iterative method for reactive jamming. Numerical experiments demonstrated that the game-theoretic approach produced a robust jamming method against smart and adaptive insurgents.

PRESENTATION:

Lin, K.Y., “Jamming Radio-Controlled Improvised Explosive Devices with Reactive Jammers,” INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

TECHNICAL REPORT:

Lin, K.Y., “Game-Theoretic Models for Jamming Radio-Controlled Improvised Explosive Devices,” Naval Postgraduate School Technical Report, NPS-OR-09-004, 2009.

THESIS DIRECTED:

Dayton, J., “Risk of using Past to Predict Future: A Case Study of Jamming RCIEDs,” Master’s Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Game Theory, Improvised Explosive Device, Probability Models

OPERATIONS RESEARCH

ANALYSIS OF CAPABILITY REQUIREMENTS FOR FORCE PROTECTION OF MILITARY, AUXILIARY, AND COMMERCIAL VESSELS OPERATING IN A CONFINED AREA

Thomas W. Lucas, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: To examine maritime force protection as part of The Technical Cooperation Program (TTCP).

SUMMARY: The Office of Naval Research (ONR) participated in a study of maritime force protection as part of The Technical Cooperation Program (TTCP). TTCP is a “five-eyes” defense science and technology organization. The objective was to evaluate potential technology solutions and accompanying tactics, techniques, and procedures (TTP) to guide future science and technology investments. This was done by evaluating multiple technical and tactical options in computational experiments of a potential force protection mission. The scenario involved an Expeditionary Strike Group (ESG) conducting humanitarian relief operations in an area with known terrorists. A simulation was developed and thousands of computational experiments were run varying the capabilities and tactics of the ESG and the threat. An analysis of the results identified potential vulnerabilities and possible technical or tactical means to overcome them.

REPORT:

McDonald, M. and Brooks, S., “TTCP Maritime Action Group 10- Scenario 2 (Expeditionary Operations - Military Vessels Underway) Final Report,” TTCP Report, 2009 (submitted).

THESIS DIRECTED:

Rayburg, C.M., “Force Protection Capability Requirements for Military, Auxiliary, and Commercial Vessels Operating in a Confined Area,” Master’s Thesis, Naval Postgraduate School, March 2009 (CONFIDENTIAL).

KEYWORDS: Design of Experiments, DOE, Humanitarian Relief, Maritime Force Protection, Simulation, The Technical Cooperation Program

FUTURE WARRIOR TECHNOLOGY AND INTEGRATION

Michael McCauley, Research Professor
Department of Operations Research
Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: The Army Future Warrior Technology Evaluation Program is being coordinated by TRAC Monterey. Human factors issues arise in many areas of this program and must be dealt with in the design and conduct of the testing program. Dr. McCauley will provide input, advice, analysis, and support, as needed, for the Future Warrior Technology and Integration evaluation program.

HUMAN FACTORS ANALYSES PERTAINING TO THE LITTORAL COMBAT SHIP

Michael McCauley, Research Professor
Department of Operations Research
Sponsor: Naval Surface Warfare Center-Panama City

OBJECTIVE: To identify human factors and HF issues pertaining to the Littoral Combat Ship (LCS) Anti-Submarine Warfare (ASW) Mission Module during ASW exercises and aboard LCS-1 during at-sea trials. Human-factors risk areas will be identified, and mitigation strategies will be recommended.

OPERATIONS RESEARCH

THE SOLDIER DOMAIN TECHNOLOGIES FIELD RESEARCH PROJECT

Michael McCauley, Research Professor

Department of Operations Research

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To assess the effectiveness of Soldier domain technologies by collecting and analyzing field data in the concurrent experiment, with emphasis on the health technologies component.

THE EFFECTS OF SLEEP ON TRAINING EFFECTIVENESS IN SOLDIERS AT FORT

LEONARD WOOD, MISSOURI

Nita L. Miller, Associate Professor

Department of Operations Research

Sponsor: Leonard Wood Institute

OBJECTIVE: Research suggests that military recruits experience a high prevalence of fatigue, which has important implications for training effectiveness, health, and safety. Prior studies used uncontrolled, descriptive-study designs that were limited to correlations between sleep and academic test performance, and many of the recommendations for follow-on research have yet to be addressed. Applied research is warranted to determine the magnitude of the effect of sleep scheduling interventions on overall training effectiveness, attrition, health, and safety. This research will implement a controlled sleep-scheduling intervention in a military training environment to quantitatively assess the effects of the intervention on recruit performance and cost effectiveness.

THE FUTURE WARFIGHTER TECHNOLOGY INTEGRATION PROJECT

Nita L. Miller, Associate Professor

Department of Operations Research

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To provide support to the Future Warrior Technology Integration Project under the direction of TRAC-Monterey. Support will span the entire project timeline, including experimental design, experimentation and data collection, and post-experimentation analysis.

IMPROVED MODELING OF HUMAN BEHAVIOR REPRESENTATION VIA MANIPULATION OF SITUATIONAL AWARENESS AND SEARCH AND TARGET ACQUISITION

Nita L. Miller, Associate Professor

Department of Operations Research

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To inform and assist the modeling and simulation (M&S) community to more accurately represent Soldier behavior, specifically by exploring the cognitive lenses of individual decision-makers. This study will involve recording the decision-making and cognitive performance of members of the military while they are subjected to deliberate changes to their individual biases and mental models or lenses. The results of this study will allow the further refinement of the Dynamic Model of Situated Cognition, ultimately resulting in the incorporation of more realistic and accurate representations of human behavior in military modeling and simulation efforts.

OPERATIONS RESEARCH

OPERATIONAL CONSEQUENCES OF HUMAN FATIGUE ON PERFORMANCE AND MANNING STRATEGIES IN MILITARY ENVIRONMENTS

Nita L. Miller, Associate Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To examine the operational consequences of human fatigue on performance in military environments. This project will assess how fatigue impacts performance in the U.S. military and will look at what fatigue countermeasures are currently being used. Test strategies will be proposed to mitigate the risks posed by under-manning and the reduced/restricted sleep regimens imposed by the military on its individual service members. Furthermore, the proposed work will result in a published guide for fatigue management for commanders to use in operational environments.

SENSOR-TO-COMMANDER METRICS

Nita L. Miller, Associate Professor
Department of Operations Research
Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To continue refinement of the Dynamic Model of Situated Cognition, to provide consultation to graduate students who are working in this field of research, and to continue development of the project.

BUSINESS CASE ANALYSIS AS&C/JCTD PROJECT SUPPORT

Daniel A. Nussbaum, Visiting Professor
Department of Operations Research
Sponsor: Office of the Under Secretary of Defense

OBJECTIVE: To provide support for business case analysis (BCA) assistance to the AS&C JCTD Office. The BCAs provide a series of rigorous analyses of the costs and benefits associated with JCTD projects, thereby providing an analytic underpinning to the decisions to begin and continue candidate projects. As a tool, the BCA is an enabling technology for overcoming the so-called “valley of death” encountered in transitioning JCTDs from project status to warfighter support. This is a significant element in a successful JCTD program. The development of a BCA will also be of great value for Naval Postgraduate School students and faculty because they get to work on current and valuable projects.

IMPROVING AND INCORPORATING COST ESTIMATING AND ANALYSIS INTO ADVANCED CONCEPT TECHNOLOGY DEMONSTRATIONS

Daniel A. Nussbaum, Visiting Professor
Department of Operations Research
Sponsor: Office of the Under Secretary of Defense

OBJECTIVE: This research was a series of studies that developed business case analyses (BCA) for specific Advanced Concept Technology Demonstrations/Joint Concept Technology Demonstrations (ACTD/JCTD). This is an ongoing effort sponsored annually by the Office of the Under Secretary of Defense (OUSD).

SUMMARY: This research provided senior DUSD (AS&C) decision-makers with improved, consistent, credible, and reliable cost estimates for use in the ACTD/JCTD Program, and included an enhanced understanding of the unique characteristics of ACTD/JCTD and provided business case analyses (BCAs) for ACTD/JCTD projects. BCAs provided a series of rigorous analyses of the costs and benefits associated with JCTD projects, thereby providing an analytic underpinning to the decisions to begin or continue candidate projects and to support transition planning with the Joint Staff.

OPERATIONS RESEARCH

PRESENTATIONS:

Nussbaum, D.A., “Cost Benefit Analysis of Integrated, COTS, Energy-Related Technologies for Army’s Force Provider Module,” Office of the Secretary of Defense, Pentagon, Washington, D.C., November 2009.

Nussbaum, D.A., “A Cost Estimation Analysis of U.S. Navy Ship Fuel Savings, Techniques, and Technologies,” Comptroller, Commander Naval Surface Forces Pacific Fleet, Naval Postgraduate School, March 2009.

Nussbaum, D.A., “Developing a United States Marine Corps Organizational and Intermediate Level Maintenance Performance Cost Model,” Headquarters, United States Marine Corps, Washington, D.C. via video teleconference from the Naval Postgraduate School, June 2009.

Nussbaum, D.A., “Geothermal HVAC Systems - A Business Case Analysis for Net Zero Plus,” Office of the Secretary of Defense, Pentagon, Washington, D.C., February 2009.

THESES DIRECTED:

Ang, C.Y., “Quantifying the Benefit of Facility-Based Mixed-Reality Training in Support of the FITE JCTD Business Case Analysis,” Master’s Thesis, Naval Postgraduate School, December 2009.

Carrasco, J.L., “A Manpower Comparison of Three U.S. Navies: The Current Fleet, a Projected 313 Ship Fleet, and a More Distributed Bimodal Alternative,” Master’s Thesis, Naval Postgraduate School, September 2009.

Clark, D., “Navy Officer Manpower Optimization Incorporating Budgetary Constraints,” Master’s Thesis, Naval Postgraduate School, March 2009.

Corley, R.M., “Evaluating the Impact of the Fully Burdened Cost of Fuel,” Master’s Thesis, Naval Postgraduate School, September 2009.

Fancher, B., “Force Structure Implications for Standing Up a Green Water Navy,” Master’s Thesis, Naval Postgraduate School, March 2009.

Fiala, D., “Force Structure Implications for Standing Up a Green Water Navy,” Master’s Thesis, Naval Postgraduate School, March 2009.

Fonte, S.V.A., “A Cost Estimation Analysis of U.S. Navy Ship Fuel-Saving Techniques and Technologies,” Master’s Thesis, Naval Postgraduate School, September 2009.

Jeanpierre, J., “Business Case Analysis of Future Immersive Training Environment (FITE) Joint Capability Technology Demonstration (JCTD),” Master’s Thesis, Naval Postgraduate School, September 2009.

Kelly, P., “United States Marine Corps Performance Pricing Model,” Master’s Thesis, Naval Postgraduate School, September 2009.

McGuire, M., “The Integration of the Naval Unmanned Combat Aerial System (N-UCAS) into the Future Naval Air Wing,” Master’s Thesis, Naval Postgraduate School, December 2009.

Riendeau, E., “Comparative Analysis of Podded versus Mechanically Driven Propulsion Systems,” Master’s Thesis, Naval Postgraduate School, March 2009.

Rivera, A., “A Cost Benefit Analysis of Integrated, COTS, Energy-Related Technologies for the Army’s Force Provider Module,” Master’s Thesis, Naval Postgraduate School, September 2009.

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Romero, A.T., II and Elliott, D.B., “Developing a United States Marine Corps Organizational and Intermediate Level Maintenance Performance Cost Model,” Master’s Thesis, Naval Postgraduate School, December 2009.

Slaybaugh, P., “A Business Case Analysis (BCA) of the One Box-One Wire (OB1) Joint Combined Technology Demonstration (JCTD),” Master’s Thesis, Naval Postgraduate School, March 2009.

Trahan, R., “Geothermal HVAC Systems – A Business Case Analysis for Net Zero Plus,” Master’s Thesis, Naval Postgraduate School, March 2009.

KEYWORDS: Cost Estimating, Business Case Analysis, Advanced Concept Technical Demonstration, ACTD, Joint Concept Technical Demonstration, JCTD

U.S. AIR FORCE QUADRENNIAL DEFENSE REVIEW SUPPORT

Daniel A. Nussbaum, Visiting Professor

Department of Operations Research

Sponsor: United States Air Force Quadrennial Defense Review

OBJECTIVE: This research consisted of projects and theses on topics identified and refined in collaboration with the Air Force Quadrennial Defense Review (AF QDR) Office. The purpose was to seek partnership opportunities with Air Force Institute of Technology to accomplish AF QDR Office research objectives.

SUMMARY: The following are the research projects and theses on topics identified and refined in collaboration with the AF QDR Office: “Alternative Energy,” Dr. Daniel Nussbaum, Operations Research Department; “Climate Change: Atmospheric Effects on Weapons Systems,” Dr. Peter Chu, Department of Oceanography; “Low Earth Orbit (LEO) Satellite Vulnerabilities,” Dr. Ramesh Kolar, Mechanical and Aerospace Engineering Department; and “Impact of Global Climate Change on U.S. Air Force Operations,” Dr. Thomas Murphree, Department of Meteorology.

THESIS DIRECTED:

Oh, J., “Application of Adaptive CERS to the Korea Helicopter Project,” Master’s Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: United States Air Force, USAF, Quadrennial Defense Review, QDR, Air Force Institute of Technology, AFIT, Collaborative Research

THE U.S. MARINE CORPS PERFORMANCE PRICING MODEL

Daniel A. Nussbaum, Visiting Professor

Department of Operations Research

Sponsor: Headquarters United States Marine Corps

OBJECTIVE: Headquarters Marine Corps (HQMC) Installations and Logistics (I&L) required an assessment of the expenditures on organizational and intermediate (O&I)-level maintenance repairables and consumables, and their effects on future budget requests. Additionally, they required analysis of the effect of O&I cost-drivers, such as inventory, and operating tempo (OPTempo), equipment age, and total procurement costs.

SUMMARY: This research focused on the following three MARFORs: 1) Marine Forces Pacific, 2) Marine Forces Command, and 3) Marine Forces Reserve. A performance-pricing model was created for the USMC planners to use as an analytical tool to support sustainment budgetary requirements in the planning, programming, budgeting, and execution (PPBE) process. A cost-estimating relationship related to maintenance costs was developed to explain the factors that affect costs and why they vary.

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THESIS DIRECTED:

Romero, A.T. II and Elliott, D.B., "Developing a United States Marine Corps Organizational and Intermediate Level Maintenance Performance Cost Model," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: Cost Estimating, Performance Pricing Model, Planning, Programming, Budgeting and Execution Process, PPBE Process

ASSESSING THE UTILITY OF SAFETY CLIMATE SURVEY DATA TO PREDICT AVIATION MISHAPS

LCDR Paul O'Connor, USN, Military Faculty and Assistant Professor
Sponsor: Department of Defense Safety Oversight Council

OBJECTIVE: To identify whether the Command Safety Assessment Survey is a valid predictor of Naval Aviation mishaps. This project supports three additional faculty members. Currently one Naval Postgraduate School report has been produced as a result of this project.

DEVELOPING A RELIABLE LEADING INDICATOR OF MISHAPS

LCDR Paul O'Connor, USN, Military Faculty and Assistant Professor
Department of Operations Research
Sponsor: Office of the Secretary of Defense

OBJECTIVE: To predict and prevent mishaps by examining the relationship between the command safety climate and aviation accidents. A relative risk scale will be developed to identify "at risk" squadrons on the basis of their safety climate.

EVALUATING THE EFFECTIVENESS OF THE NAVY'S CREW RESOURCE MANAGEMENT PROGRAM

LCDR Paul O'Connor, USN, Military Faculty and Assistant Professor
Department of Operations Research
Sponsor: Office of Naval Personnel

OBJECTIVE: To provide an objective measure of the effectiveness of the Navy's Crew Resource Management (CRM) Program, identify techniques for benchmarking CRM training effectiveness, and provide techniques to allow commanding officers to carry out periodic reviews of the CRM training being delivered in their squadrons.

SUMMARY: As part of this project, two papers were submitted to a journal for publication, and a conference paper, two book chapters, and two theses were written. This project supported one additional faculty member.

EVALUATING THE EFFECTIVENESS OF SURFACE AND SUB-SURFACE SIMULATORS TO TRAIN NON-TECHNICAL SKILLS

LCDR Paul O'Connor, USN, Military Faculty and Assistant Professor
Department of Operations Research
Sponsor: Navy Office of Modeling and Simulation

OBJECTIVE: To identify how simulators are being used to train personnel in the surface and sub-surface Navy, with a particular focus on non-technical skills. Non-technical skills are cognitive, social, and

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personal resource skills that complement technical skills and contribute to safe and effective task performance. This project supported one additional faculty member.

PUBLICATION:

O'Connor, P., Hyde, D., and Clarke, J., "Torso Heating of Divers in Cold Water," *Aviation Space and Environmental Medicine*, 80, 603-609, 2009.

CONFERENCE PUBLICATION:

O'Connor, P. and Jones, D., "The Crew Resource Management Attitudes of U.S. Naval Aviators," *Human Factors and Ergonomics Society Conference*, San Antonio, Texas, September 2009.

CONTRIBUTIONS TO BOOKS:

Campbell, J. and O'Connor, P., "Coping with Stress in Military Aviation: A Review of the Research," *Human Performance Enhancements in High-Risk Environments: Insights, Developments, and Future Directions from Military Research*, P. O'Connor and J. Cohn (Eds.), pp. 169-188, Santa Barbara, California: ABC-Clio, 2010.

O'Connor, P., Hahn, R., and Salas, E., "The U.S. Navy's Crew Resource Management Program: The Past, Present, and Recommendations for the Future," *Human Performance Enhancements in High-Risk Environments: Insights, Developments, and Future Directions from Military Research*, P. O'Connor and J. Cohn (Eds.), pp. 90-105, Santa Barbara, California: ABC-Clio, 2010.

BOOK:

O'Connor, P. and Cohn, J. (Eds.), *Human Performance Enhancements in High-Risk Environments: Insights, Developments, and Future Directions from Military Research*, Santa Barbara, California: ABC-Clio, 2010.

REPORT:

O'Connor, P., O'Dea, A., Kennedy, Q., and Butterrey, S., "A Review of the Safety Climate Literature as It Relates to Naval Aviation," Naval Postgraduate School, 2010.

CHAIR OF INNOVATION
CAPT Douglas Otte, USN, Military Faculty
Department of Operations Research
Sponsor: Navy Warfare Development Command

OBJECTIVE: To update the Navy Warfare Development Command (NWDC) Chair of Innovation at the Naval Postgraduate School (NPS). Since 2002, the NWDC has leveraged the chair's position to invigorate and conduct the research and analysis required to develop doctrine, tactics, techniques, procedures, and joint maritime concepts of operations. The chair continues to act as the liaison for collaborative efforts between NPS research institutes and graduate schools and the NWDC. These collaborative efforts continue to provide valuable opportunities for faculty and student professional development at NPS, while enhancing the NWDC's mission to foster Naval innovation. This updated memorandum of understanding (MOU) enhances the original MOU by providing the option of establishing a co-chair civilian faculty to work in coordination with a Navy officer as chair. The co-chair would provide longer-term continuity between the two.

OPERATIONS RESEARCH

OPERATIONS-RESEARCH ANALYTICAL MODELS FOR THE CUSTOMS AND BORDER PATROL TUNNEL PROBLEM

Steven E. Pilnick, Senior Lecturer

Department of Operations Research

Sponsor: U.S. Army Training and Doctrine Analysis Center Monterey,
U. S. Customs and Border Patrol

OBJECTIVE: To apply quantitative models and modeling approaches of search and detection theory to the Customs and Border Patrol (CBP) tunnel operational problem involving sensors and targets in order to evaluate effectiveness and allocate resources.

SUMMARY: Analytical models primarily using equations and spreadsheets were developed to examine the CBT Tunnel problem across the three geography types (urban, suburban, and rural) with parameterized sensor performance in appropriate corresponding geology environments. The models included quantification of the border-zone tunnel threat. Parameters were used to represent the extent of border zones, classification of geography and geology types, location distribution, and tunnel threat. The analysis examined alternatives for sensor deployment patterns, coverage, and spacing. The models evaluated the operational effectiveness of the alternatives in reducing the probability that targets successfully penetrate the border undetected by use of tunnels, and generated rough order-of-magnitude estimates for the resources required for the various alternatives.

REPORT:

Pilnick, S., Bachl, C., Bakken, A., Basova, H., Cizek, R., Col, S., et al., "Customs and Border Patrol Tunnel Problem Search and Detection Analysis," Report to TRADOC Analysis Center Monterey, September 2009.

KEYWORDS: Border Tunnels, Search and Detection, Operations Analysis

ADAPTIVE PRECISION ADJUSTMENT FOR EFFICIENT OPTIMIZATION OF COMPLEX SYSTEMS

Johannes O. Royset, Assistant Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To develop algorithms for solving difficult optimization problems where the objective and/or constraint functions cannot be computed exactly but must be approximated. In particular, this research will focus on the construction of efficient precision adjustment schemes for controlling the approximations within algorithms.

SUMMARY: This research was directed towards three classes of optimization problems: 1) stochastic programs, where functions are defined in terms of expectations; 2) semi-infinite programs, where functions are non-smooth max-functions; and 3) optimal control problems, where functions are given by the solution of ordinary and partial differential equations. In 2009, major advances were achieved on problems of class one, i.e., stochastic programs, and results were obtained that showed the potential for significant computational savings when the precision of approximations was controlled by a discrete-time optimal-control problem. Preliminary results on semi-infinite programs and optimal control problems were also obtained.

PUBLICATIONS:

Rockafellar, R.T. and Royset, J.O., "On Buffered Failure Probability in Design and Optimization of Structures," *Reliability Engineering and System Safety* (to appear).

Royset, J.O., "Optimality Functions in Stochastic Programming," (submitted).

OPERATIONS RESEARCH

Royset, J.O., “On Sample Size Control in Sample Average Approximations for Solving Smooth Stochastic Programs,” (submitted).

PRESENTATIONS:

Engineering Risk Control and Optimization Conference, Gainesville, Florida, February 2009.

Guest lecture at Molde University College, Norway, May 2009.

Szechtman, R., INFORMS Applied Probability Society Conference, Ithaca, New York, July 2009.

THESES AND DISSERTATIONS DIRECTED:

Basova, H., “Optimization using the Buffered Failure Probability,” Master’s Thesis, Naval Postgraduate School, June 2010.

Foraker, J., “Optimal Search in Continuous Time: Models and Algorithms,” Ph.D. Dissertation, Naval Postgraduate School, June 2011.

Pee, E.Y., “Robust Optimization using Semi-Infinite Optimization,” Ph.D. Dissertation, Naval Postgraduate School, December 2010.

Vondrak, D., “Control of Sample Size in Stochastic Programming with Application to Logistics,” Master’s Thesis, Naval Postgraduate School, March 2009.

KEYWORDS: Nonlinear Optimization, Stochastic Programming, Semi-Infinite Optimization, Optimal Control

ASYMPTOTIC ANALYSIS OF SAMPLE ALLOCATION IN STOCHASTIC OPTIMIZATION

Johannes O. Royset, Assistant Professor

Roberto Szechtman, Assistant Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: In the sample average approximation context, the allocation of the computing budget that leads to the fastest convergence in distribution to an optimal solution will be determined.

SUMMARY: Many problems require optimization of a function that can be expressed as the expectation of a function of random variables. In the context of sample average approximation, the principal investigators (PIs) studied the efficient allocation of the computing budget between two competing demands: generating samples to reduce uncertainty about sample averages, and carrying out iterations of an optimization algorithm. Nonlinear optimization algorithms can typically be characterized by a convergence rate, which affects the resulting allocation. The PIs analyzed the case of a single starting point and of multiple starting points, the later being appropriate for optimization of non-convex functions. It was found that for linear and super-linear convergent optimization algorithms, little effort is directed to algorithm iteration.

PUBLICATIONS:

Kaplan, E., Kress, M., and Szechtman, R., “Confronting Entrenched Insurgents,” *Operations Research*, 2009 (to appear).

Kress, M. and Szechtman, R., “Why Defeating Insurgencies is Hard: The Effect of Intelligence in Counterinsurgency Operations – A Best Case Scenario,” *Operations Research*, 57, pp. 578-585, 2009.

OPERATIONS RESEARCH

Royset, J.O. and Szechtman, R., “Asymptotic Analysis of Sample Allocation in Stochastic Optimization,” (in preparation).

PRESENTATION:

Royset, J.O. and Szechtman, R., “A New Perspective on Computing Budget Allocation for Sample Average Approximation,” 15th INFORMS Applied Probability Society Conference, Ithaca, New York, July 2009.

KEYWORDS: Stochastic Optimization, Sample Average Approximation, Central Limit Theorem

EFFICIENT OPTIMIZATION OF COMPLEX SYSTEMS

Johannes O. Royset, Assistant Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To derive a framework for managing approximations in design optimization of complex engineering systems.

U.S. NAVY MANPOWER OPTIMIZATION: SUPPORT FOR THESIS RESEARCH AND TOOL DEVELOPMENT

Javier Salmerón, Associate Professor

Department of Operations Research

Sponsor: U.S. Navy Manpower, Personnel, Training, and Education, N1

OBJECTIVE: To guide the Manpower, Personnel, Training, and Education’s (MPTE) Navy Strategic Resourcing Branch with complex budgetary decisions, and to reduce the mismatch between officer work requirements and actual executable budget.

SUMMARY: Research has been performed to guide the MPTE’s Navy Strategic Resourcing Branch with complex budgetary decisions and monthly values for officer inventory, promotions, accessions, designator transfers, and losses (forced and natural). The work involved the development of mathematical optimization models (which represent the interactions among those decisions), their computational implementation, and the analysis of the results they produce. The models developed attempt to minimize a measure of “gap” based on the level of fulfillment of select job requirements by community, rank, and period of time (month), but limited by certain fiscal and policy constraints.

PRESENTATIONS:

Salmerón, J., Clark, D., and Wheeler, M., “Navy Officer Manpower Optimization,” Navy Workforce Research and Analysis Conference, Washington, D.C., 12-14 May 2010 (scheduled).

Salmerón, J. and Clark, D., “Navy Officer Manpower Optimization Incorporating Budgetary Constraints,” INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

THESES DIRECTED:

Clark, D., “Navy Officer Manpower Optimization Incorporating Budgetary Constraints,” Master’s Thesis, Naval Postgraduate School, March 2009.

Wheeler, M., “Navy Officer Manpower Optimization with Fiscal Constraints Revisited,” Master’s Thesis, Naval Postgraduate School, March 2010.

KEYWORDS: Manpower Planning, Optimization

OPERATIONS RESEARCH

COGNITIVE COMMAND-AND-CONTROL CAPABILITIES FOR AGENT-BASED-MODEL— ENABLED DATA FARMING FOR PLANNING TESTS IN JOINT MISSION ENVIRONMENTS

**Paul Sanchez, Senior Lecturer
Department of Operations Research
Sponsor: Naval Air Systems Command**

OBJECTIVE: There is a need to conduct testing in a complex, joint-mission environment across the acquisition lifecycle to improve a program manager's ability to deliver joint capabilities to war fighters. For a joint mission environment with many interdependent systems, assessing individual system and system-of-systems (SOS) contributions to joint mission effectiveness becomes extremely challenging. A change in system may have cascading effects across the mission environment; furthermore, many of these systems may be at different points in development and acquisition. This complex, adaptive, SOS environment makes it nearly impossible to plan decent tests using current test methods and capabilities. Cogent planning for the tests of these complex, adaptive systems involves a very tedious, almost impossible, test planning process for determining what and how to test. To do this efficiently, new test and evaluation (T&E) tools, methods, and processes are needed. The Naval Postgraduate School SEED Center proposes to build on previous work to: 1) define the technical characteristics required for agent-based models to be used for exploring C2 structures and the associated cognitive and social processes of the human components of the C2 structures in a joint mission environment; 2) develop a C2-enabled agent-based model (ABM) to capture C2 structures and their associated human cognitive and social processes and use them, along with developing technologies, to test what-if questions in a variety of SOS environments and scenarios; and 3) develop an interface to facilitate rapid construction of these C2-enabled ABMs.

REPRESENTING PLAN EXECUTION IN A DYNAMIC BATTLEFIELD ENVIRONMENT

**Lawrence Shattuck, Senior Lecturer
Department of Operations Research
Sponsor: Army Research Laboratory**

OBJECTIVE: The U.S. Army Research Laboratory Human Research and Engineering Directorate oversees and conducts research with the Advanced Decision Research Collaborative Alliance. Additional resources are required from the Naval Postgraduate School (NPS) for successful execution of the ADA CTA research task, Dynamic Planning Tools for RAPTOR, led by Wright State University (WSU). Researchers and students at NPS will work with the researchers and programmers at WSU to develop computer-based tactical scenarios. These scenarios will pennant comparison of C2 performance between RAPTOR and current FBCB2 interface designs. Data will be collected on U.S. Army officers stationed at the Naval Postgraduate School and the U.S. Military Academy.

THE SOLDIER DOMAIN TECHNOLOGY INTEGRATION EXPERIMENTATION AND ANALYSIS PROJECT

**Lawrence Shattuck, Senior Lecturer
Department of Operations Research
Sponsor: TRADOC Analysis Center-Monterey**

OBJECTIVE: To conduct human systems integration research of emerging technologies (i.e., unmanned systems) to verify their potential for providing increased combat effectiveness. The Naval Postgraduate School (NPS), with TRAC-Monterey as the lead, will identify issues for analysis, develop experimental designs, and finalize data collection and analysis plans. Further insights into the impact of these capabilities during the Soldier Domain Technologies Project live experimentation will be augmented with constructive simulation experimentation and analysis, as appropriate.

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CUSTOMS AND BORDER PATROL PROTECTION DATA ANALYSIS

Lyn R. Whitaker, Associate Professor

Department of Operations Research

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To identify the areas and conditions under which there is a high risk for tunneling on the border between Mexico and the United States. This is part of a larger effort headed by TRAC-Monterey to make recommendations to the Customs and Border Protection Agency (CBP) about how and what type of sensors to deploy along the U.S. borders to identify tunneling. This portion of the work involves a preliminary exploration of available data on tunnels (types of tunnels, uses, locations, etc.) and any other social (e.g., levels of criminal activity), geographic (e.g., water tables), or U.S. Border Patrol activities (fencing, patrolling, etc.) that might inhibit or encourage tunneling. Ultimately, the goal is to statistically model the risk of tunneling as a function of these various factors.

STATISTICAL ANALYSIS OF TUNNEL DATA

Lyn R. Whitaker, Associate Professor

Samuel E. Buttrey, Assistant Professor

Department of Operations Research

Sponsor: TRAC-Monterey

OBJECTIVE: To identify the areas and conditions under which there is a high risk for tunneling on the border between Mexico and the United States. This is part of a larger effort headed by TRAC-Monterey to make recommendations to the Customs and Border Protection Agency (CBP) about what type of sensors to deploy along U.S. borders to identify tunneling. This portion of the work involves collection and exploration of data available about existing (detected) tunnels (e.g., types of tunnels, uses, locations, etc.). These data came from multiple sources with varying levels of precision and accuracy.

SUMMARY: This work marked the first time this data had been subjected to rigorous examination. A large number of inconsistencies and inaccuracies were detected. The work characterized tunnels as being short and unsophisticated, long and sophisticated, or, most commonly, taking advantage of pre-existing infrastructure. In fact, the majority of tunnels in the data were of this final sort, predominantly in the cross-border drainage tunnels in and near Nogales, Arizona. The ability to characterize tunnels by cargo (undocumented personnel, drugs, or weapons) is limited, and it does not appear to be the case that soil type is a determinant of tunnel activity except for the shortest and least sophisticated tunnels. It may be long and sophisticated tunnels that are of the greatest concern. The principal investigators noted that outside metropolitan areas these tunnels almost always connect existing buildings and showed that locations for tunnels of this sort can be found using a geographic information system.

PUBLICATION:

TRAC technical report delivered to CBP.

STATISTICAL MODELING OF IMPROVISED EXPLOSIVE DEVICE EVENTS AND BLUE FORCE ACTIVITIES IN A DYNAMIC ENVIRONMENT (PART OF THE NPS-JIEDDO FULL SPECTRUM RESEARCH PROJECT)

Lyn R. Whitaker, Associate Professor

Samuel E. Buttrey, Associate Professor

Robert A. Koyak, Associate Professor

Department of Operations Research

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: The statistical models developed in this work provide preliminary tools with which information obtained from the battlefield can be used to assess the risk of improvised explosive device (IED) events accounting for Blue Force presence and other important factors. Their purpose is to provide

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easily usable visualizations of the risk of IEDs for use in theater, identify data shortfalls and critical driving factors, assess effectiveness of countermeasures, and serve as a template for “what-if” analysis.

SUMMARY: This is part of continuing work begun in FY08. These efforts fall into three broad categories. The first uses survival analysis to statistically model the risk of IED events on major roads (MSRs and ASRs) and, more generally, on road networks. Theoretical development and progress towards implementation are contained in Professor Koyak’s two papers: “Risk on Roads: A Modeling Approach,” Parts I (Estimation) and II (Refinement and Implementation).

The second effort is the statistical modeling of IED events in an urban environment. The principal investigators estimate the intensities of IED events, which are statistically rare, accounting for Blue Force activities and other variables. This work and initial pilot studies applying these methods to the Iraq theater of operations are reported in the paper “Statistical Models of IED Events in an Urban Environment: An Expedient Approach” by Professors Whitaker and Buttrely and the four SECRET Master’s theses completed in 2009.

The third area of study, reported in the works mentioned above, is computational, algorithmic, and data support. This is the underpinning of all the statistical work to which all of the PIs, but particularly Professor Buttrely, contribute.

PRESENTATIONS:

Weko, C., “Procedures for Interpreting and Visualizing Blue Force Tracker Data,” JIEDDO IPR, Washington, D.C., 6 November 2009.

Weko, C., “Procedures for Interpreting and Visualizing Blue Force Tracker Data,” Military Operations Research Society/Tisdale Award Presentation, Monterey, California, 3 December 2009.

THESES DIRECTED:

Bruce, R., “Data Preparation and Output Presentation Methodologies in Blue Force Tracker (BFT)-Related IED Risk Assessment Modeling,” Master’s Thesis, Naval Postgraduate School, September 2009.

Landin, M., “Analysis of IED Risk in an Urban Environment,” Master’s Thesis, Naval Postgraduate School, June 2009.

Sykes, M., “Assessing IED Risk with Respect to Blue Force Presence and Measurement and Signature Intelligence (MASINT),” Master’s Thesis, Naval Postgraduate School, June 2009.

Weko, C., “Procedures for Interpreting and Visualizing Blue Force Tracker Data,” Master’s Thesis, Naval Postgraduate School, December 2009.

A SEQUENTIAL PERSPECTIVE ON SEARCHING FOR STATIC TARGETS

LCDR Kurt E. Wilson

Roberto Szechtman, Assistant Professor

Michael Atkinson, Assistant Professor

Department of Operations Research

Sponsor: GEE

OBJECTIVE: To present a sequential perspective on imperfect sensor employment applicable to static targets that is easy to implement, is computationally tractable for a larger class of problems than the optimization approaches currently being employed, and stops when the user-prescribed probabilistic guarantees are met.

SUMMARY: A sequential approach was presented to detect static targets with imperfect sensors, which range from tower-mounted cameras to satellites. The scenario is operationally relevant to many military, homeland security, search and rescue, environmental engineering, counter-narcotics, and law enforcement

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applications. The idea is to stop the search as soon as there is enough probabilistic evidence about the targets' locations, given an operator-prescribed error tolerance, knowledge of the sensors' parameters, and a sequence of detection signals from the sensors. By stopping the search as soon as possible, efficiency is promoted by freeing up sensors and operators to perform other tasks. The model developed in this research has the added benefit of decreasing operator workload and providing negative information as a search progresses.

PUBLICATION:

Wilson, K.E., Szechtman, R., and Atkinson, M.P., "A Sequential Perspective on Searching for Static Targets," *European Journal of Operational Research* (submitted).

THESIS DIRECTED:

Wilson, K.E., "Efficient Employment of Imperfect Search Sensors in Complex Environments," Master's Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: Search Theory, Sequential Analysis

INTERDICTING THE IMPROVISED EXPLOSIVE DEVICE SUPPLY CHAIN

R. Kevin Wood, Distinguished Professor

Javier Salmerón, Associate Professor

LTC Lee Ewing, USA, Military Faculty and Assistant Professor

Department of Operations Research

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To develop and implement a model for optimal interdiction of smuggled improvised explosive devices (IEDs) and IED components.

SUMMARY: A game-theoretic model was applied to the interdiction of IEDs and/or IED components. The model identified an optimal, randomized strategy for allocating limited search teams along road segments. The model was also implemented using the VBA programming language (Visual Basic for Applications), and that was embedded within an Excel-based graphical user interface. The implementation handled networks with up to 100,000 road segments and any number of homogeneous search teams. An investigation of methods to represent multiple types of search assets, e.g., UAVs, ground teams, electronic sensors, has also begun.

THESIS DIRECTED:

Unsal, O., "Two-Person Zero-Sum Games for Network Interdiction with Multiple Inspector Types," Master's Thesis, Naval Postgraduate School, June 2010.

KEYWORDS: Network Interdiction, Improvised Explosive Devices, Search and Detection

LARGE-SCALE NETWORK ALGORITHMS

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: National Security Agency

OBJECTIVE: To provide support for continuing research on attacker-defender problems, and to provide travel support for Naval Postgraduate School faculty to deliver presentations on current research and to discuss future research topics.

DEPARTMENT OF OPERATIONS RESEARCH

**2009
Faculty Publications
and Presentations**

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Atkinson, M.P., Guetz, A., and Wein, L.M., "A Dynamic Model for Post-Traumatic Stress Disorder among U.S. Troops in Operation Iraqi Freedom," *Management Science*, 55, 1454-1468, 2009.

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Johnson, R.T. and Montgomery, D.C., "Choice of Second-Order Response Surface Designs for Logistic and Poisson Regression Models," *International Journal of Experimental Design and Process Optimisation*, 1, pp. 2-23, 2009.

Johnson, R.T., Parker, P.A., Montgomery, D.C., Cutler, A.D., Danehy, P.M., and Rhew, R.D., "Design Strategies for Response Surface Models for the Study of Supersonic Combustion," *Quality and Reliability Engineering International*, 25, pp. 365-377, 2009.

Jones, B. and Johnson, R.T., "The Design and Analysis of the Gaussian Process Model," *Quality and Reliability Engineering International*, 25, pp. 515-524, 2009.

Kress, M. and Szechtman, R., "Why Defeating Insurgencies is Hard: The Effect of Intelligence in Counterinsurgency Operations – A Best Case Scenario," *Operations Research*, 57, pp. 578-585, 2009.

Lin, K.Y. and Sibdari, S., "Dynamic Price Competition with Discrete Customer Choices," *European Journal of Operational Research*, 197(3), 969-980, 2009.

Lin, K.Y., Kress, M., and Szechtman, R., "Scheduling Policies for an Antiterrorist Surveillance System," *Naval Research Logistics*, 56(2), 113-126, 2009.

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O'Connor, P., Hyde, D., and Clarke, J., "Torso Heating of Divers in Cold Water," *Aviation Space and Environmental Medicine*, 80, 603-609, 2009.

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Royset, J.O., Carlyle, W.M., and Wood, R.K., "Routing Military Aircraft with a Constrained Shortest-Path Algorithm," *Military Operations Research*, 14(3), pp. 31-52, 2009.

Salmerón, J., Wood, K., and Baldick, R., "Worst-Case Interdiction Analysis of Large-Scale Electric Power Grids," *IEEE Transactions on Power Systems*, 24, pp. 96-104, 2009.

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Hasting, M., Chung, T.H., and Evangelista, P., "Experimentation and Modeling of Soldier Target Search," *Proceedings of the International Conference on Industrial Engineering, Theory, Applications and Practice*, Anaheim, California, 2009.

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O'Connor, P. and Jones, D., "The Crew Resource Management Attitudes of U.S. Naval Aviators," *Human Factors and Ergonomics Society Conference*, San Antonio, Texas, September 2009.

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Rice, J. and Ramp, S., "San Francisco Bayweb 2009," *ACM SenSys Workshop on Under-Water Networking*, Berkeley, California, 3 November 2009.

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Johnson, R.T., “Applied Experiment Design for an Autonomous Search Simulation,” INFORMS, San Diego, California, October 2009.

Johnson, R.T., “Comparing Designs for Simulation Experiments,” International Data Farming Workshop 18, Monterey, California, March 2008.

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Marlin, B., Lucas, T.W., Larson, A., and Sanchez, S.M., “Developing and Assessing Irregular Warfare Models to Support IED Interdiction and Mitigation,” INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

Morrice, D.J., Butler, J.C., and Regnier, E.D., “An Empirical Analysis of Hurricane Sales and Weather Data,” Production and Operations Management Society 2009 Conference, Orlando, Florida, 1-4 May 2009.

Nussbaum, D.A., “Cost Benefit Analysis of Integrated, COTS, Energy-Related Technologies for the Army’s Force Provider Module,” Office of the Secretary of Defense, Pentagon, Washington, D.C., November 2009.

Nussbaum, D.A., “A Cost Estimation Analysis of U.S. Navy Ship Fuel Savings, Techniques, and Technologies,” Comptroller, Commander Naval Surface Forces Pacific Fleet, Monterey, California, March 2009.

Nussbaum, D.A., “Developing a United States Marine Corps Organizational and Intermediate Level Maintenance Performance Cost Model,” Headquarters, United States Marine Corps, Washington, D.C. via video teleconference from Monterey, California, June 2009.

Nussbaum, D.A., "Geothermal HVAC Systems - A Business Case Analysis for Net Zero Plus," Office of the Secretary of Defense, Pentagon, Washington, D.C., February 2009.

Ramp, S., Rice, J., Stacey, M., Williams, M., Largier, J., Garfield, T., and Bahr, F., "SF Bayweb 2009, Planting the Seeds of a New Observing System in the San Francisco Bay," Eastern Pacific Ocean Conference, Victoria, British Columbia, Canada, 23-26 September 2009.

Regnier, E.D., "Forecasting for Decision Support," Departmental Seminar, Department of Applied Math and Statistics, University of California, Santa Cruz, 2 November 2009.

Regnier, E.D., "Impact of Improving Intensity Forecasts," INFORMS Annual Meeting, San Diego, California, 11 October 2009.

Royset, J.O., "Adaptive Control of Sample Size in Stochastic Optimization," Engineering Risk Control and Optimization Conference, Gainesville, Florida, February 2009.

Royset, J.O., "Operations Research at the Naval Postgraduate School," Norwegian Defense Research Institute, Norway, May 2009.

Royset, J.O., "Path Optimization for Multiple Searchers," International Symposium on Mathematical Programming, Chicago, Illinois, August 2009.

Royset, J.O., "Stochastic Optimization with Applications to Investment and Routing Problems," Molde University College, Norway, May 2009.

Royset, J.O. and Szechtman, R., "A New Perspective on Computing Budget Allocation for Sample Average Approximation," INFORMS Applied Probability Society Conference, Ithaca, New York, 2009.

Salmerón, J. and Clark, D., "Navy Officer Manpower Optimization Incorporating Budgetary Constraints," INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

Salmerón, J., Baldick, R., and Wood, K., "Worst-Case Interdiction, and Defense, of Large-Scale Electric Power Grids," 20th International Symposium on Mathematical Programming, Chicago, Illinois, 23-28 August 2009.

Sanchez, S.M., "SEED Center for Data Farming: Top-Level Overview," JIEDDO Agent-Based Modeling Workshop, Carderock, Virginia, 22-23 September 2009.

Sanchez, S.M., Lucas, T.W., and Sanchez, P.J., "Better than a Petaflop: The Power of Efficient Experimental Design," International Data Farming Workshop 19, Auckland, New Zealand, 1-6 November 2009.

Sanchez, S.M., Lucas, T.W., and Sanchez, P.J., "Design of Experiments," International Data Farming Workshop 18, Monterey, California, 22-27 March 2009.

Walsh, W., "Maritime Information Sharing Taskforce: Capturing the Voice of Maritime Industry in Information Sharing," AIAA Homeland Security Conference, Monterey, California, 3 September 2009.

Walsh, W., "Maritime Information Sharing Taskforce: Capturing the Voice of Maritime Industry in Information Sharing," Global Maritime Information Sharing Symposium, Washington D.C., 16 September 2009.

Weko, C., "Procedures for Interpreting and Visualizing Blue Force Tracker Data," JIEDDO IPR, Washington, D.C., 6 November 2009.

OPERATIONS RESEARCH

Weko, C., "Procedures for Interpreting and Visualizing Blue Force Tracker Data," Military Operations Research Society/Tisdale Award Presentation, Monterey, California, 3 December 2009.

Whitaker, L.R., Buttrey, S.E., and Koyak, R.A., "Statistical Modeling of IED Events," JIEDDO Senior Mentors Brief, Monterey, California, 11 August 2009.

Whitaker, L.R., Buttrey, S.E., and Koyak, R.A., "Statistical Modeling of IED Events in a Dynamic Environment," JIEDDO, Alexandria, Virginia, 14 September 2009.

Wood, K. and Salmerón, J., "U.S. Power Grids: Evaluating and Mitigating Vulnerability to Terrorist Attack," INFORMS Annual Meeting, San Diego, California, 11-14 October 2009.

CONTRIBUTIONS TO BOOKS

Campbell, J. and O'Connor, P., "Coping with Stress in Military Aviation: A Review of the Research," *Human Performance Enhancements in High-Risk Environments: Insights, Developments, and Future Directions from Military Research*, P. O'Connor and J. Cohn (Eds.), pp. 169-188, Santa Barbara, California: ABC- Clio, 2010.

Dell, R.F., Roman, P.E., and Velasquez, J.D., "Web User Session Reconstruction with Back Button Browsing," *Knowledge-Based and Intelligent Information and Engineering Systems*, Springer, Berlin, 2009.

Gaver, D.P., Jacobs, P.A., and Glazebrook, K.D., "Search for a Malevolent Needle in a Benign Haystack," *Game Theoretic Risk Analysis of Security Threats, Chapter 6*, V.M. Bier and M.N. Azaiez (Eds.), International Series in Operations Research and Management Science, Vol. 128, New York: Springer, 2009.

Kline, J., "Maritime Security," *Securing the Global Commons*, S. Jasper (Ed.), Stanford Press, 2010.

O'Connor, P., Hahn, R., and Salas, E., "The U.S. Navy's Crew Resource Management Program: The Past, Present, and Recommendations for the Future," *Human Performance Enhancements in High-Risk Environments: Insights, Developments, and Future Directions from Military Research*, P. O'Connor and J. Cohn (Eds.), pp. 90-105, Santa Barbara, California: ABC-Clio, 2010.

BOOK

O'Connor, P. and Cohn, J. (Eds.), *Human Performance Enhancements in High-Risk Environments: Insights, Developments, and Future Directions from Military Research*, Santa Barbara, California: ABC-Clio, 2010.

POSTER

Taylor, J.L., Adamson, M.M., Samarina, V., Kennedy, Q., Yesavage, J.A., and Weiner, M.W., "Larger Hippocampi Help Expert Pilots Maintain Performance in a Flight Simulator," International Neuropsychological Society Annual Conference, Atlanta, Georgia, 2009.

WHITE PAPER

Davidson, K.L., Frederickson, P.A., and Huynh, T.V., "NPS System-of-Systems Exploitation of Knowledge of Atmospheric and Ocean Surface Impacts for MIO and Maritime Security," White Paper prepared for Commander, Navy Meteorology and Oceanography Command, 9 pp., February 2009.

OPERATIONS RESEARCH

TECHNICAL REPORTS

Apte, A., Rendon, R., and Salmerón, J., “Sourcing in the Air Force: An Optimization Approach,” Naval Postgraduate School Technical Report, NPS-LM-09-131, 2009.

Koyak, R., “Risk on Roads: A Modeling Approach. Part I: Estimation Models,” 2009 (revised March 2009).

Koyak, R.A., “Risk on Roads: A Modeling Approach. Part II: Model Refinement and Implementation,” 19 pp., September 2009.

Lin, K.Y., “Game-Theoretic Models for Jamming Radio-Controlled Improvised Explosive Devices,” Naval Postgraduate School Technical Report, NPS-OR-09-004, 2009.

O’Connor, P., O’Dea, A., Kennedy, Q., and Buttery, S., “A Review of the Safety Climate Literature as It Relates to Naval Aviation,” Naval Postgraduate School, 2010.

Pilnick, S., Bachl, C., Bakken, A., Basova, H., Cizek, R., Col, S., et al., “Customs and Border Patrol Tunnel Problem Search and Detection Analysis,” Report to TRADOC Analysis Center-Monterey, September 2009.

Salem, A., Walsh, W., and Englehorn, L., “Industry and Public Sector Cooperation for Information Sharing: Ports of the Puget Sound,” Naval Postgraduate School Technical Report, July 2009.

Salmerón, J. and Wood, K., “Final Report on DOE Research Project DE-AI02-05ER25670: Reducing the Vulnerability of Electric Power Grids to Terrorist Attacks,” Project Report, Naval Postgraduate School, NPS-OR-09-003-PR, 2009 (restricted access).

Washburn, A.R., “Barrier Games,” Naval Postgraduate School Technical Report, NPS-OR-09-001, June 2009.

**GRADUATE SCHOOL OF
ENGINEERING AND
APPLIED SCIENCES**

**SIVAGURU S. SRITHARAN
DEAN**

**DEPARTMENT OF
APPLIED MATHEMATICS**

**CARLOS F. BORGES
CHAIRMAN**

APPLIED MATHEMATICS

OVERVIEW:

The Naval Postgraduate School (NPS) Department of Applied Mathematics is deeply committed to excellence. Our mission is to provide an exceptional mathematical education focused on the unique needs of our students, to engage in relevant research, and to provide quality service to the community. We are deeply committed to maintenance of a well-designed curriculum and a supportive environment for our students.

CURRICULA SERVED:

The majority of the departmental effort is devoted to the service courses offered, which support almost every curriculum on campus.

DEGREES GRANTED:

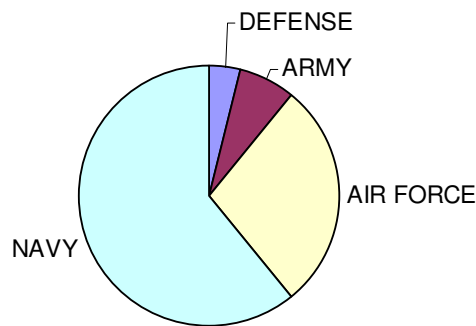
- Master of Science in Applied Mathematics
- Doctor of Philosophy

RESEARCH THRUSTS:

- Applied Analysis
- Numerical Analysis/Scientific Computation
- Discrete Mathematics

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Applied Mathematics is provided below:



Size of Program: \$532K

APPLIED MATHEMATICS

Carlos F. Borges
Professor and Chair
831-656-2124
borges@nps.edu

Frank Giraldo
Professor and Associate Chair for Research
831-656-2293
fxgiraldo@nps.edu

David R. Canright
Associate Professor
831-656-2782
dcanright@nps.edu

Christopher L. Frenzen
Associate Professor
831-656-2435
cfrenzen@nps.edu

Beny Neta
Professor
831-656-2235
bneta@nps.edu

Lester E. Carr
Lecturer
831-656-3629
lecarr@nps.edu

Ralucca Gera
Assistant Professor
831-656-2206
rgera@nps.edu

Guillermo Owen
Distinguished Professor
831-656-2720
gowen@nps.edu

Donald A. Danielson
Professor
831-656-2622
dad@nps.edu

William B. Gragg
Professor
831-656-2194
gragg@nps.edu

Craig W. Rasmussen
Associate Professor
831-656-2763
ras@nps.edu

Doyle Daughtry
Lecturer
831-656-3478
doughtr@nps.edu

Wei Kang
Professor
831-656-3337
wkang@nps.edu

Clyde Scandrett
Professor
831-656-2027
cscand@nps.edu

Fariba Fahroo
Professor
831-656-2664
ffahroo@nps.edu

Arthur J. Krener
Distinguished Visiting
Professor
831-656-2664
ajkrener@nps.edu

Pantelimon (Pante) Stanica
Professor
831-656-2714
pstanica@nps.edu

Harold M. Fredricksen
Professor
831-656-3249
half@nps.edu

Bard K. Mansager
Senior Lecturer
831-656-2695
bardman@nps.edu

Hong Zhou
Associate Professor
831-656-2600
hzhou@nps.edu

APPLIED MATHEMATICS

NEXT-GENERATION GLOBAL ATMOSPHERIC MODELS

Francis X. Giraldo, Associate Professor

Department of Applied Mathematics

Sponsor: Office of Naval Research (Battlespace Environments)

OBJECTIVE: The U.S. Navy would like to replace its existing global atmospheric model, which relies on leapfrog time-stepping, and to by-pass the time-step restriction caused by vertically propagating acoustic waves and spectral transform methods to approximate the spatial derivatives. To this end, the principal investigators (PIs) propose to develop spectral element and discontinuous Galerkin methods that are high-order accurate, conserve all variables, permit the use of unstructured adaptive grids, and scale extremely well on distributed-memory computers. To by-pass the time-step restriction, the PIs propose to develop semi-implicit time-integrators.

PUBLICATIONS:

Giraldo, F.X. and Restelli, M., “High-Order Semi-Implicit Methods for a Discontinuous Galerkin Oceanic Shallow Water Model,” *International Journal for Numerical Methods in Fluids*, 2009.

Giraldo, F.X. and Restelli, M., “A Semi-Implicit Method for a High-Order Triangular Discontinuous Galerkin Oceanic Shallow Water Model,” *International Journal for Numerical Methods in Fluids*, 2009 (in press).

PRESENTATION:

Giraldo, F.X., Alevras, D., and Radko, T., “Simulation of the 2004 Indian Ocean Tsunami with Real Bathymetry using a Triangular Discontinuous Galerkin Model,” SIAM Conference in Computational Science and Engineering, Miami, Florida, 2009.

THESIS DIRECTED:

Alevras, D., “Simulating Tsunamis in the Indian Ocean with Real Bathymetry by using a High-Order Triangular Discontinuous Galerkin Oceanic Shallow Water Model,” Master’s Thesis, Naval Postgraduate School, March 2009. (Student was awarded the 2009 Spring International Student award partly due to this thesis.)

KEYWORDS: Discontinuous Galerkin, Euler Equations, Navier-Stokes, Spectral Element, Implicit Methods

NEXT-GENERATION GLOBAL AND MESOSCALE ATMOSPHERIC MODELS

Francis X. Giraldo, Associate Professor

Department of Applied Mathematics

Sponsor: Office of Naval Research

OBJECTIVE: The U.S. Navy would like to replace their existing second-order, finite-difference, mesoscale (regional)-atmospheric model that relies on leapfrog time-stepping and split-explicit algorithms to by-pass the time-step restriction caused by vertically propagating acoustic waves. To this end, the principal investigators (PIs) propose to develop spectral element and discontinuous Galerkin methods that are high-order accurate, conserve all variables, permit the use of unstructured adaptive grids, and scale extremely well on distributed-memory computers. In addition, the PIs propose to use a different form of the governing equations for these models, that being the fully compressible Navier-Stokes equations. To by-pass the time-step restriction, the PIs propose to develop semi-implicit time-integrators.

PUBLICATIONS:

Giraldo, F.X. and Restelli, M., “A Conservative Semi-Implicit Discontinuous Galerkin Method for the Navier-Stokes Equations in Nonhydrostatic Mesoscale Atmospheric Modeling,” *SIAM Journal on Scientific Computing*, 2009.

Giraldo, F.X., Dea, J.R., and Neta, B., “High-Order Non-Reflecting Boundary Conditions for Linearized Euler - No Mean Flow Case,” *Wave Motion*, 2009.

Giraldo, F.X., Lindquist, J.M., and Neta, B., “Klein-Gordon Equation with Advection on Unbounded Domains using Spectral Elements and High-Order Non-Reflecting Boundary Conditions,” *Applied Mathematics and Computation*, 2009 (in review).

Giraldo, F.X., Lindquist, J.M., and Neta, B., “A Spectral Element Solution of the Klein-Gordon Equation with High-Order Treatment of Time and Non-Reflecting Boundary,” *Wave Motion*, 2009 (in press).

Giraldo, F.X., Restelli, M., and Läuter, M., “Semi-Implicit Formulations for the Compressible Navier-Stokes Equations in Mesoscale Atmospheric Modeling,” *SIAM Journal on Scientific Computing*, 2009 (in review).

Giraldo, F.X., Läuter, M., Reich, S., Restelli, M., Dethloff, K., and Handorf, D., “Unified Hydrostatic/Nonhydrostatic Discontinuous Galerkin Formulations for the Navier-Stokes Equations,” *Quarterly Journal of the Royal Meteorological Society*, 2009 (in review).

PRESENTATIONS:

Giraldo, F.X., “Continuous and Discontinuous Galerkin Methods for Compressible Navier-Stokes,” University of Karlsruhe, Karlsruhe, Germany, June 2009 (invited by Professor Vincent Heuveline).

Giraldo, F.X., “Why Do We Need More Atmospheric Models?” Alfred-Wegener Institute, Potsdam, Germany, July 2009 (invited by Professor Klaus Dethloff).

Giraldo, F.X., Kelly, J., and Carr, L., “Fully-Implicit Methods for the Compressible Navier-Stokes Equations,” American Geophysical Union Conference, San Francisco, California, December 2009.

Giraldo, F.X., Restelli, M., and Läuter, M., “Semi-Implicit Methods for the Compressible Navier-Stokes Equations,” SIAM Conference on Mathematics in the Geosciences, Leipzig, Germany, 2009.

Giraldo, F.X., Restelli, M., and Läuter, M., “A Semi-Implicit Spectral Element Mesoscale Atmospheric Model,” 2009 Workshop on Partial Differential Equations on the Sphere, Santa Fe, New Mexico, April 2009.

Giraldo, F.X., Läuter, M.M., Handorf, D., and Dethloff, K., “A Discontinuous Galerkin Mesoscale Atmospheric Model,” 2009 Workshop on Partial Differential Equations on the Sphere, Santa Fe, New Mexico, April 2009.

THESES DIRECTED:

Dea, J., “High-Order Non-Reflecting Boundary Conditions for the Linearized Euler Equations,” Ph.D. Dissertation, Naval Postgraduate School, September 2008.

Gibbons, S., “Coordinate Transformations of the Euler Equations with Steep Terrain,” Master’s Thesis, Naval Postgraduate School.

Lindquist, J., “Non-Reflecting Boundary Conditions for High-Order Continuous Galerkin Approximations of Hyperbolic Systems of Equations,” PhD Dissertation, Naval Postgraduate School.

POSTDOCTORAL WORK DIRECTED:

Kelly, J., “Developing Numerical and Parallel Algorithms for the Compressible Navier-Stokes Equations,” completed the first year of his National Research Council (NRC) research fellowship.

KEYWORDS: Discontinuous Galerkin, Euler Equations, Navier-Stokes, Spectral Element, Implicit Methods

DATA ASSIMILATION USING PSEUDOSPECTRAL OPTIMAL CONTROL

Wei Kang, Professor
Department of Applied Mathematics
Sponsor: Naval Research Laboratory

OBJECTIVE: To explore the potential and advantage of applying the state-of-the-art in Optimal Control Theory to the problem of data assimilation. More specifically, the research focus is on the application of pseudospectral (PS) optimal control to the problem of data assimilation subject to nonlinear dynamics. The goal is to develop discretization methods based upon PS optimal control that uses fewer nodes than conventional approaches, which implies a relatively lower dimension in the discretized nonlinear optimization.

OBSERVABILITY IN DATA ASSIMILATION AND OPTIMAL SENSOR CONFIGURATION

Wei Kang, Professor
Department of Applied Mathematics
Sponsor: Naval Research Laboratory

OBJECTIVE: To develop mathematical concepts and numerical algorithms for the evaluation and optimal design of sensor configuration in data assimilations.

The objective of this project is to develop mathematical concepts and numerical algorithms for the evaluation and optimal design of sensor configurations in data assimilations. The technical objectives include: 1) applying concepts of observability to the problem of data assimilation and numerically testing the concepts using a mid-size model; 2) developing computational algorithms that are scalable to large-size problems; and 3) developing problem formulation and computational algorithms for maximizing the observability of forecast models by finding optimal sensor locations.

PUBLICATIONS:

Kang, W., Ross, I.M., Pham, K., and Gong, Q., “Autonomous Observability of Networked Multi-Satellite Systems,” *AIAA Journal of Guidance, Control, and Dynamics*, Vol. 32, No. 3, 869-877, 2009.

Zhou, H., Kang, W., Krener, A.J., and Wang, H., “Observability of Viscoelastic Fluids,” *Journal of Non-Newtonian Fluid Mechanics* (to appear).

CONFERENCE PUBLICATION:

Kang, W. and Xu, L., “A Quantitative Measure of Observability and Controllability,” *Proceedings of the IEEE Conference on Decision and Control*, Shanghai, China, 2009.

PRESENTATION:

Kang, W., “Some Issues on Dynamical Systems: Observability, Controllability, and Dynamic Optimization,” Workshop on Computational Issues in Nonlinear Control, Monterey, California, November 2009.

CONTRIBUTION TO BOOK:

Kang, W., Barbot, J.-P., and Xu, L., "On the Observability of Nonlinear and Switched Systems," *Emergent Problems in Nonlinear Systems and Control*, B. Ghosh and C.F. Martin (Eds.), Springer (to appear).

PSEUDOSPECTRAL OPTIMAL CONTROL OF NONLINEAR SYSTEMS

Wei Kang, Professor

Department of Applied Mathematics

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To develop practical methods to solve highly nonlinear, optimal-control problems, and to prove the efficiency of the method by proving the feasibility and convergence. The fundamental concept in the approach is based on the Pseudospectral Approximation Theory of Numerical Computation, and nonlinear programming for complicated optimization problems.

SUMMARY: For some important families of nonlinear systems, the feasibility and convergence of the pseudospectral optimal-control method are proved. In addition, the Covector Mapping Theorem, an important result that bridges the optimal state in a control system with the necessary conditions of optimal control, is proved for general nonlinear systems. In 2007 and 2008, several new theorems on convergence were proved that significantly simplified and reduced the assumptions relative to the theorems proved in 2006. In addition, the convergence results were generalized to problems with discontinuous optimal control.

PUBLICATIONS:

Bedrossian, N., Bhatt, S., Kang, W., and Ross, I.M., "Zero-Propellant Maneuver Guidance: Rotating the International Space Station with Computational Dynamic Optimization," *Control Systems Magazine*, Vol. 29, No. 5, 53-73, 2009.

Kang, W., "Rate of Convergence for a Legendre Pseudospectral Optimal Control of Feedback Linearizable Systems," *Journal of Control Theory and Applications*, (to appear).

Wilson, L., Zhou, H., and Kang, W., "Controllability of Non-Newtonian Fluids under Homogeneous Extensional Flow," *Applied Mathematical Sciences*, (to appear).

SENSOR-TO-COMMANDER METRICS

Wei Kang, Professor

Department of Applied Mathematics

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To develop a mathematical theory and computational algorithms for the optimal control of information flow. Given the complexity of this problem, no existing methodologies or algorithms can satisfactorily solve the optimal control problem. Therefore, a new theory and algorithms must be developed. This is the step of research in which we must face some essential difficulties and challenges that call for innovative ideas and approaches.

NUMERICAL SOLUTION OF FIRST-ORDER PARTIAL-DIFFERENTIAL EQUATIONS OF NONLINEAR CONTROL

Arthur J. Krener, Distinguished Visiting Professor
Department of Applied Mathematics
Sponsor: Air Force Office of Scientific Research

SUMMARY: There are two types of first-order partial-differential equations that arise over and over again in many algorithms for the control and estimation of nonlinear systems. These types are the Hamilton Jacobi Bellman PDEs (HJB PDEs) and Intertwining PDEs (ITW PDEs). Solutions to one or both these PDEs are essential parts of many algorithms for nonlinear control and estimation, yet there are few effective methods for their solution when the state dimension is greater than two or three.

Researchers propose to develop new, higher-order methods for solving such equations. These will combine power series techniques, Cauchy-Kovalevskaya techniques, patchy techniques, and fast sweeping methods.

NUMERICAL SOLUTION OF FIRST-ORDER PARTIAL-DIFFERENTIAL EQUATIONS OF NONLINEAR CONTROL

Arthur J. Krener, Distinguished Visiting Professor
Department of Applied Mathematics
Sponsor: Air Force Office of Scientific Research, Dynamics and Control

OBJECTIVE: There are great needs for effective algorithms to control highly nonlinear plants, such as modern aircraft and spacecraft. Fortunately, there has been great progress in nonlinear control theory over the last three decades, and many of the needed algorithms have been developed. However, their implementation has lagged behind. The principle reason for this is computational. There are few effective computational methods available to solve the nonlinear, partial-differential equations that are required by the nonlinear theory. This is in contrast to linear control where the theory has been complimented by excellent numerical methods, such as those in the MATLAB Control Toolbox. The goal of this research is to develop the numerical tools needed to solve Hamilton Jacobi Bellman PDEs and others that arise in nonlinear control theory. The principal investigators (PIs) propose to develop high-order numerical schemes that can handle systems with up to six-to-twelve state variables. To do so, the PIs shall take advantage of the fact that most of the PDEs that arise in nonlinear control admit power series solutions in a neighborhood of an operating point and the lowest terms of these series can be computed by linear algorithms. This yields a solution on some patch of the state space containing the operating point. The PIs propose to extend the solution on other patches encircling the original patch. This will be done using the techniques of Cauchy-Kovalevskaya and fast sweeping and marching methods.

PRESENTATIONS:

Krener, A.J., "Computational Issues in Nonlinear Control," Naval Postgraduate School Workshop on Computational Control, Monterey, California, November 2009.

Krener, A.J., "Numerical Solution of the First Order Partial Differential Equations of Nonlinear Control," AFOSR Contractors Meeting, Washington, D.C., July 2009.

THESIS DIRECTED:

Hunt, T., Ph.D. in Applied Mathematics, University of California, Davis.

KEYWORDS: Hamilton Jacobi Bellman PDE, Francis Byrnes Isidori PDE, Kazantsis Kravaris PDE

APPLIED MATHEMATICS

A WORKSHOP ON COMPUTATIONAL ISSUES IN NONLINEAR CONTROL

Arthur J. Krener, Distinguished Visiting Professor
Department of Applied Mathematics
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To organize the Workshop on Computational Issues in Nonlinear Control. The topics to be addressed include HJ and HJB equations; numerical calculation of optimal trajectories; and numerical calculation of invariant manifolds. The goal of this workshop is to bring together three different communities of researchers to exchange ideas and to stimulate future research in this area.

MANHUNTING A SEARCH FOR A MOVING FUGITIVE

Guillermo Owen, Distinguished Professor
Department of Applied Mathematics
Sponsor: United States Military Group Bogota, Colombia

OBJECTIVE: To conduct an academic seminar in Bogota, Colombia, from 21-25 September 2009, with the sponsorship of the Naval Postgraduate School, Monterey, California. The goal is to expose selected civilian and military personnel from the national defense and security sector to the theoretical models of operational investigation and research in order to provide the analytical tool to resolved complex military challenges.

THE EIGHTH INTERNATIONAL SYMPOSIUM ON TECHNOLOGY AND THE MINE PROBLEM

Clyde Scandrett, Professor and Chair
Department of Applied Mathematics
Sponsor: Office of Naval Research

OBJECTIVE: To help support the planning and execution of a technical symposium on mines. The purpose of the symposium is to continue the examination of the potential for emergent technologies to enhance the capabilities of the U.S. and its allies in mining, mine countermeasures, and humanitarian demining, including remediation. The themes of this symposium will be technologies for mine warfare, expeditionary warfare, and harbor protection/port security. As with the seven preceding symposia, this symposium is a joint undertaking of several U.S. government agencies. The planned dates for the eighth symposium are 6-8 May 2008.

AN INVESTIGATION OF ACOUSTIC CLOAKING

Clyde Scandrett, Professor and Chair
Department of Applied Mathematics
Sponsor: Naval Undersea Warfare Center-Newport Division

OBJECTIVE: To reimburse the principal investigator (PI) for actual house rental, car rental, and travel expenses while working in Newport, Rhode Island. The PI will undertake an investigation of the viability of underwater acoustic cloaking with collaborators at the Naval Undersea Warfare Center (NUWC)-Division Newport. While at NUWC, the PI will also participate in the Scientist Exchange Program established by the 4 April MOU between the Naval Postgraduate School and NUWC.

APPLIED MATHEMATICS

AN INVESTIGATION OF ACOUSTIC CLOAKING

Clyde Scandrett, Professor

Department of Applied Mathematics

Sponsor: Naval Undersea Warfare Center-Newport Division

OBJECTIVE: In collaboration with Naval Undersea Warfare Center (NUWC) researchers, an analytical study of the feasibility of cloaking, recently reported in the E&M literature, in acoustics. Initial work will bear on what is theoretically possible, while other researchers at NUWC will focus on a class of meta-materials capable of realizing the analytical potential.

SUMMARY: After a thorough review of the literature, a hybrid method using pentamode materials possessing anisotropy in both bulk moduli and density was investigated. Difficulties with unrealizable mass or stiffness were addressed by utilizing a combination of anisotropies in both density and bulk moduli in an effort to create cloaks comprised of realistic materials. Ultimately, it was found that at specified frequency ranges it is possible to optimize acoustic cloaking with a small number of pentamode types with piecewise constant densities.

PUBLICATION:

Scandrett, C., Boisvert, J., and Howarth, T., "Acoustic Cloaking using Layered Pentamode Materials," *Journal of the Acoustical Society of America*, (accepted).

KEYWORDS: Acoustics, Cloaking, Metamaterials

THE NINTH INTERNATIONAL SYMPOSIUM ON TECHNOLOGY AND THE MINE PROBLEM

Clyde Scandrett, Professor and Chair

Department of Applied Mathematics

Sponsor: Office of Naval Research

OBJECTIVE: To support the planning and execution of a technical symposium on mines. The purpose of the symposium is to continue the examination of the potential for emergent technologies to enhance the capabilities of the U.S. and its allies in mining, mine countermeasures, and humanitarian demining, including area remediation. The themes of this symposium will be technologies for mine warfare, expeditionary warfare, and harbor protection/port security, with an emphasis on the use of unmanned systems. As with the eight preceding symposia, this symposium is a joint undertaking of several U.S. government agencies. The planned dates for the eighth symposium are 17-21 May 2010.

KEYWORDS: Mines, Mining, Undersea Warfare

MATHEMATICAL MODELING, ANALYSIS, AND SCIENTIFIC COMPUTATION OF COMPLEX FLUIDS

Hong Zhou, Associate Professor

Department of Applied Mathematics

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To develop robust and efficient numerical methods and codes to solve the kinetic equations and mesoscopic tensor equations for rod-like polymers in the presence of flows and external fields; to characterize solution behavior of the Smoluchowski Equation of General Potentials; and to study the effects of weak compressibility on complex fluids.

SUMMARY: Liquid crystalline polymers and nanocomposites have wide-ranging applications in Air Force and Navy products. The final goal of this research is to understand the performance features of these

technologically important materials, and thereby, to provide insight into the development of future materials with desirable properties.

Recent work included: 1) providing a comprehensive study on the planar orientational distributions of nematic polymers under an imposed shear flow of arbitrary strength; 2) studying the effects of different physical parameters on the efficiency of a thermoelectric generator; 3) investigating the observability of various viscoelastic fluids under imposed shear of extensional flows; and 4) analyzing the phase-diagram of nematic, liquid-crystal polymer monolayers with the Onsager intermolecular potential.

PUBLICATIONS:

Wang, H. and Zhou, H., “Phase Diagram of Nematic Polymer Monolayers with the Onsager Interaction Potential,” *Journal of Computational and Theoretical Nanoscience* (in press).

Wang, H., Zhou, H., and Forest, M.G., “Sheared Nematic Liquid Crystal Polymer Monolayers,” *Discrete and Continuous Dynamical Systems-Series B*, 11(2), 497-517, 2009.

Zhou, H., “Efficiency of Inhomogeneous Thermoelectric Generators,” *Applied Mathematical Sciences*, 4(11), 505-514, 2010.

Zhou, H., Forest, M.G., and Wang, H., “Mathematical Studies and Simulations of Nematic Liquid Crystal Polymers and Nanocomposites,” *Journal of Computational and Theoretical Nanoscience* (in press).

Zhou, H., Kang, W., Krener, A., and Wang, H., “Observability of Viscoelastic Fluids,” *Journal of Non-Newtonian Fluid Mechanics* (in press).

**DEPARTMENT OF
APPLIED MATHEMATICS**

**2009
Faculty Publications
and Presentations**

JOURNALS

Bedrossian, N., Bhatt, S., Kang, W., and Ross, I.M., “Zero-Propellant Maneuver Guidance: Rotating the International Space Station with Computational Dynamic Optimization,” *Control Systems Magazine*, Vol. 29, No. 5, 53-73, 2009.

Giraldo, F.X. and Restelli, M., “A Conservative Semi-Implicit Discontinuous Galerkin Method for the Navier-Stokes Equations in Nonhydrostatic Mesoscale Atmospheric Modeling,” *SIAM Journal on Scientific Computing*, 2009.

Giraldo, F.X. and Restelli, M., “High-Order Semi-Implicit Methods for a Discontinuous Galerkin Oceanic Shallow Water Model,” *International Journal for Numerical Methods in Fluids*, 2009.

Giraldo, F.X. and Restelli, M., “A Semi-Implicit Method for a High-Order Triangular Discontinuous Galerkin Oceanic Shallow Water Model,” *International Journal for Numerical Methods in Fluids*, 2009 (in press).

Giraldo, F.X., Dea, J.R., and Neta, B., “High-Order Non-Reflecting Boundary Conditions for Linearized Euler - No Mean Flow Case,” *Wave Motion*, 2009.

Kang, W., Ross, I.M., Pham, K., and Gong, Q., “Autonomous Observability of Networked Multi-Satellite Systems,” *AIAA Journal of Guidance, Control, and Dynamics*, Vol. 32, No. 3, 869-877, 2009.

Wang, H., Zhou, H., and Forest, M.G., “Sheared Nematic Liquid Crystal Polymer Monolayers,” *Discrete and Continuous Dynamical Systems-Series B*, 11(2), 497-517, 2009.

Zhou, H., “Efficiency of Inhomogeneous Thermoelectric Generators,” *Applied Mathematical Sciences*, 4(11), 505-514, 2010.

CONFERENCE PUBLICATION

Kang, W. and Xu, L., “A Quantitative Measure of Observability and Controllability,” *Proceedings of the IEEE Conference on Decision and Control*, Shanghai, China, 2009.

PRESENTATIONS

Giraldo, F.X., “Continuous and Discontinuous Galerkin Methods for Compressible Navier-Stokes,” University of Karlsruhe, Karlsruhe, Germany, June 2009 (invited by Professor Vincent Heuveline).

Giraldo, F.X., “Why Do We Need More Atmospheric Models?” Alfred-Wegener Institute, Potsdam, Germany, July 2009 (invited by Professor Klaus Dethloff).

Giraldo, F.X., Alevras, D., and Radko, T., “Simulation of the 2004 Indian Ocean Tsunami with Real Bathymetry using a Triangular Discontinuous Galerkin Model,” SIAM Conference in Computational Science and Engineering, Miami, Florida, 2009.

Giraldo, F.X., Kelly, J., and Carr, L., “Fully-Implicit Methods for the Compressible Navier-Stokes Equations,” American Geophysical Union Conference, San Francisco, California, December 2009.

Giraldo, F.X., Restelli, M., and Läuter, M., “Semi-Implicit Methods for the Compressible Navier-Stokes Equations,” SIAM Conference on Mathematics in the Geosciences, Leipzig, Germany, 2009.

Giraldo, F.X., Restelli, M., and Läuter, M., “A Semi-Implicit Spectral Element Mesoscale Atmospheric Model,” 2009 Workshop on Partial Differential Equations on the Sphere, Santa Fe, New Mexico, April 2009.

Giraldo, F.X., Läuter, M.M., Handorf, D., and Dethloff, K., “A Discontinuous Galerkin Mesoscale Atmospheric Model,” 2009 Workshop on Partial Differential Equations on the Sphere, Santa Fe, New Mexico, April 2009.

Kang, W., “Some Issues on Dynamical Systems: Observability, Controllability, and Dynamic Optimization,” Workshop on Computational Issues in Nonlinear Control, Monterey, California, November 2009.

Krener, A.J., “Computational Issues in Nonlinear Control,” Naval Postgraduate School Workshop on Computational Control, Monterey, California, November 2009.

Krener, A.J., “Numerical Solution of the First Order Partial Differential Equations of Nonlinear Control,” AFOSR Contractors Meeting, Washington, D.C., July 2009.

**DEPARTMENT OF
ELECTRICAL AND
COMPUTER ENGINEERING**

**R. CLARK ROBERTSON
CHAIRMAN**

ELECTRICAL AND COMPUTER ENGINEERING

OVERVIEW:

The Department of Electrical and Computer Engineering (ECE) has a broad research program, reflecting the variety of skills and interests of the faculty. ECE faculty research projects are supported by systems commands, warfare centers, the services, basic-research agencies, other universities, and industry. These research projects are grouped into ten major areas of emphasis that support the curricula served by the department and Department of Defense plans. Unique to the ECE Department and the Naval Postgraduate School (NPS) is the ability of faculty and students to perform military-relevant classified research at all levels. The department's research program ensures that our graduate students will have a creative and meaningful thesis experience, our curricula and courses will remain at the cutting edge, we can recruit and retain quality faculty, and we can provide our sponsors with cutting-edge solutions to their problems.

CURRICULA SERVED:

- Electronic Systems Engineering
- Information Warfare
- Electronic Warfare
- Space-Systems Operations
- Space-Systems Engineering
- Undersea Warfare
- Joint C4I Systems
- Information Technology Management
- Systems Engineering

DEGREES GRANTED:

- Master of Science in Electrical Engineering
- Master of Science in Engineering Science
- Master of Engineering (Electrical Engineering)
- Electrical Engineer
- Doctor of Philosophy

RESEARCH THRUST AREAS:

- Communications and Signal Processing
- Electric Power and Control
- Network Engineering
- Sensor Systems Engineering
- Computers and Microelectronics

LABORATORIES:

- Nano-Electronics Laboratory
- Circuits, Signals, and Digital Systems Laboratory
- Academic Computing Laboratory
- Microwave and Antenna Laboratory
- Optical Electronics Laboratory
- Radar and Electronic-Warfare Systems Laboratory
- Controls and Robotics Laboratory
- Power Systems Laboratory

ELECTRICAL AND COMPUTER ENGINEERING

- Digital Signal Processing Laboratory
- Computer Communications and Networking Laboratory
- Secure Computing Laboratory
- Communications Research Laboratory
- Signal Enhancement Laboratory

RESEARCH CENTERS:

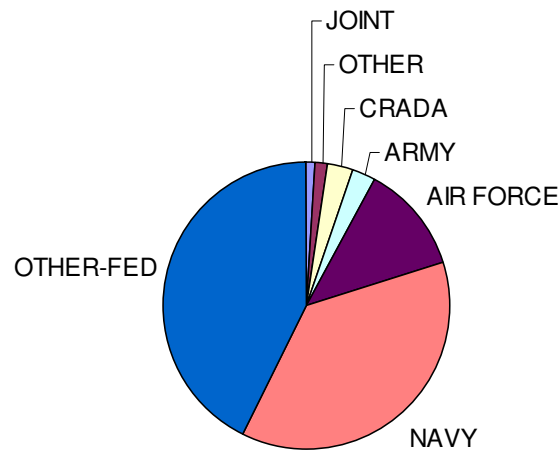
- Center for Cyber Warfare
- Center for Joint Services Electronic Warfare
- Center for Reconnaissance Research
- Center for Signal Processing
- Center for Radiation Hardened Electronics
- Communications Research Center

RESEARCH CHAIR:

- National Security Agency Cryptologic Chair

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Electrical and Computer Engineering is provided below:



Size of Program: \$3.2M

ELECTRICAL AND COMPUTER ENGINEERING

R. Clark Robertson
Chairman and Professor
831-656-2383
crobertson@gmail.com

Douglas J. Fouts
Professor
Associate Dean of Research
831-656-2852
fouts@nps.edu

Ronald G. Aikins
Research Professor
831-656-3213
rgaikins@nps.edu

Robert W. Ashton
Associate Professor
831-656-2928
ashton@nps.edu

Peter R. Ateshian
Visiting Lecturer
831-656-2255
prateshi@nps.edu

Jon T. Butler
Professor
831-656-3299
butler@nps.edu

Roberto Cristi
Professor
831-656-2223
cristi@nps.edu

Monique P. Fargues
Professor
831-656-2859
fargues@nps.edu

Vicente Garcia
Professor of Practice

Tri T. Ha
Professor
831-656-2788
ha@nps.edu

Robert G. Hutchins
Associate Professor
831-656-3289
hutchins@nps.edu

David C. Jenn
Professor
831-656-2254
jenn@nps.edu

Alexander L. Julian
Assistant Professor
831-656-2101
ajulian@nps.edu

Jeffrey B. Knorr
Professor Emeritus
831-656-2815
jknorr@nps.edu

Frank Kragh
Associate Professor
831-656-7502
fekragh@nps.edu

Herschel H. Loomis
Professor
831-656-3214
loomis@nps.edu

John C. McEachen
Professor
831-656-3652
mceachen@nps.edu

James Bret Michael
Professor
831-656-2655
bmichael@nps.edu

Sherif N. Michael
Professor
831-656-2252
michael@nps.edu

Michael A. Morgan
Distinguished Professor
831-656-2677
mmorgan@nps.edu

David Neely
Associate Chair
and Military Professor
831-656-2233
dsneely@nps.edu

Giovanna Oriti
Research Assistant Professor
831-656-2637
goriti@nps.edu

Phillip E. Pace
Professor and Director
Center for Joint Services
Electronic Warfare
831-656-3286
pepace@nps.edu

Alan A. Ross
Professor of Practice
831-656-3769
aross@nps.edu

Weilian Su
Associate Professor
831-656-3217
weilian@nps.edu

Frederick W. Terman
Senior Lecturer
831-656-2178
terman@nps.edu

Murali Tummala
Professor
831-656-2645
mtummala@nps.edu

Wilbur R. Vincent
Research Associate Professor
831-656-2753
wrvincen@nps.edu

Todd Weatherford
Associate Professor
831-656-3044
trweathe@nps.edu

Xiaoping Yun
Professor
831-656-2629
yun@nps.edu

Lawrence J. Ziomek
Professor
831-656-3206
ziomek@nps.edu

ELECTRICAL AND COMPUTER ENGINEERING

ADVANCED POWER SYSTEMS MODELS AND DESIGN METHODS FOR ELECTRICAL DISTRIBUTION

Robert W. Ashton, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Carderock Division

SUMMARY: The planning, design, and operation of shipboard power systems require comprehensive analyses to evaluate system performance and to ascertain the effectiveness of alternative plans for system improvements. The objective of the design is to create a power system that meets the needs of the warfighter as an integrated part of a total ship system.

This proposal presents an integrated design and simulation methodology that allows power system designers to work in a total ship system context to perform the necessary engineering studies prior to designing a new electrical power system or expanding an existing system.

ELECTROMAGNETIC AIRCRAFT LAUNCH SYSTEM POWER ELECTRONICS PERFORMANCE EVALUATION

Robert W. Ashton, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To provide expert electromagnetic aircraft launch system (EMALS) prime power interface subsystem (PPIS) and power conversion subsystem (PCS) power electronics technical consultation. This includes device, controller, and algorithm design calculation review and interfaces, test plans, and procedure review of solid-state power-electronic-based power conversion devices supporting EMALS design, production, and testing.

BENT FUNCTIONS FOR CRYPTOGRAPHY

Jon T. Butler, Professor

Department of Electrical and Computer Engineering

Pantelimon Stanica, Associate Professor

Department of Applied Mathematics

Sponsor:

OBJECTIVE: To apply the reconfigurable computer as a research tool for Boolean functions for cryptography. For example, the focus of this research is on bent functions because they are the most nonlinear of all Boolean functions and they are resilient to linear attacks. With a reconfigurable computer, the architecture can be adapted to the problem, thus achieving significant speed ups.

SUMMARY: It is shown that the reconfigurable computer [1] can achieve speeds of up of 60,000 over a conventional computer in bent function discovery [3]. This is significant given that the clock of the conventional computer runs at 2,800 MHz, while the reconfigurable computer runs at 100 MHz. The transeunt triangle [2] was introduced as a means to reduce the search space for bent functions, and a reduction in the search space of more than a 1,000,000 to 1 was achieved.

PUBLICATIONS:

[1] Butler, J.T., Dueck, G.W., Yanushkevich, S., and Shmerko, V.P., "On the Use of Transeunt Triangles to Synthesize Fixed-Polarity Reed-Muller Expansions of Functions," *Proceedings of the Reed-Muller Workshop 2009*, 119-126, Naha, Okinawa, Japan, 23-24 May 2009.

[2] Butler, J.T. and Sasao, T., "Logic Functions for Cryptography - A Tutorial," *Proceedings of the Reed-Muller Workshop 2009*, pp. 127-136, Naha, Okinawa, Japan, 23-24 May 2009.

[3] Shafer, J.L., Schneider, S.W., Butler, J.T., and Stanica, P., "Enumeration of Bent Boolean Functions by Reconfigurable Computer," 17 January 2010 (submitted).

PRESENTATIONS:

Butler, J.T., "Bent Functions – Theory and Practice," Kyushu Institute of Technology, Japan, 14 May 2009.

Butler, J.T., "Logic Functions in Cryptology," presented to Dr. F. Ben Cole, III, DISL-7, of NSA, Naval Postgraduate School, 9 November 2009.

Butler, J.T., "Logic Functions for Cryptography - A Tutorial," Reed-Muller 2009 Workshop, Naha, Okinawa, Japan, 24 May 2009.

Butler, J.T., "On the Use of Transeunt Triangles to Synthesize Fixed-Polarity Reed-Muller Expansions of Functions," Reed-Muller 2009 Workshop, Naha, Okinawa, Japan, 24 May 2009.

THESES DIRECTED:

Alexopolous, A., "Covering Radius of Reed-Muller Codes," Master's Thesis, Naval Postgraduate School, December 2009.

Shafer, J., "An Analysis of Bent Function Properties using the Transeunt Triangle and the SRC-6 Reconfigurable Computer," Master's Thesis, Naval Postgraduate School, September 2009.

Schafer, N., "Characteristics of the Binary Decision Diagrams of Bent Boolean Functions," Master's Thesis, Naval Postgraduate School, September 2009.

Schneider, S., "Finding Bent Functions using Genetic Algorithms," Master's Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: Cryptography, Bent Functions, Decryption/Encryption, Reconfigurable Computing

DECISION DIAGRAM MACHINES

Jon T. Butler, Professor

Department of Electrical and Computer Engineering

Sponsor:

OBJECTIVE: To develop efficient, high-speed implementations of decision diagrams. Specifically, the goal is to produce designs of machines in which the instructions manipulate data in decision diagrams and transfer flow of control to specified parts of the decision diagram.

SUMMARY: High-Speed Decision Diagram Machines. For more than 25 years, researchers have used decision diagrams to analyze and synthesize logic circuits. Indeed, decision diagrams are part of many systems applications used to design and simulate complex logic designs. However, decision diagrams have predominantly been implemented in software. In an effort to achieve high speeds, approaches were developed in which the decision diagram implementation is in hardware. More specifically, a computer [1] was developed such that the instructions directly implement a decision diagram. A unique aspect of this project is the direct involvement of engineers from an electronic firm, Renesas of Tokyo.

PUBLICATION:

Sasao, T., Nakahara, H., Matsuura, M., Kawamura, Y., Kajiwara, H., and Butler, J.T., "A Quaternary Decision Diagram Machine: Optimization of Its Code," Special Section on Multiple-Valued Logic and VLSI Computing, *IEICE Transaction on Information and Systems*, August 2010. The editors invited this paper to be part of the Special Section. It is an extended version of Sasao, T., et al., "A Quaternary

Decision Diagram Machine and the Optimization of Its Code,” *Proceedings of the International Symposium on Multiple-Valued Logic*, pp. 362-369, Naha, Okinawa, Japan, 21-23 May 2009.

KEYWORDS: Decision Diagrams, Binary Decision Diagrams, BDDs, Quaternary Decision Diagrams, QDDs, Direct Machine Implementation

HIGH-SPEED NUMERIC-FUNCTION GENERATORS

Jon T. Butler, Professor

Department of Electrical and Computer Engineering

Sponsor:

OBJECTIVE: To produce efficient designs for logic circuits that realize numeric functions, such as $f(x) = \sin(x)$. The design is easily adapted to a range of commonly used functions, including trigonometric functions, 2^x , $\log x$, entropy function, sigmoid function, and Gaussian function. An important characteristic is that composite functions can be easily implemented. For example, the composite $\log(\sin(\sqrt{x}))$ is as easily realized as any single function.

SUMMARY: High-Speed Numeric Function Generators [1]: This year’s contributions include: 1) extending results to two variable functions [4,7]; and 2) developing an approach that accommodates floating point numbers [2,6] (previous research focused on fixed point numbers). The research team extended their knowledge of the use of decision diagrams in designing numeric function generators [3,6]. The team was also able to show how the circuit complexity depends on the specified approximation error and the function realized [5]. Previously, this information could only be determined experimentally.

PUBLICATIONS:

[1] Butler, J.T., Sasao, T., and Nagayama, S., “Numeric Function Generators,” *The 3rd International Symposium on Information Electronics Systems*, Sendai, Japan, pp. 26-29, 13-15 July 2009 (invited). (This paper was one of six invited papers for this conference.)

[2] Nagayama, S., Sasao, T., and Butler, J.T., “Floating-Point Numerical Function Generators using EVBDDs for Monotone Elementary Functions,” *Proceedings of the 39th International Symposium on Multiple-Valued Logic*, Naha, Okinawa, Japan, pp. 349-355, 21-23 May 2009.

[3] Nagayama, S., Sasao, T., and Butler, J.T., “Numerical Function Generators using Decision Diagrams for Discrete Functions,” *Proceedings of the 18th International Workshop on Post-Binary ULSI Systems*, Naha, Okinawa, Japan, pp. 36-41, 20 May 2009.

[4] Nagayama, S., Sasao, T., and Butler, J.T., “Programmable Architectures and Design Methods for Two-Variable Numeric Function Generators,” *IPSJ Transactions on System LSI Design Methodology*, Vol. 3, No. 2, pp. 118-129, February 2010. (This journal paper is the extension of two conference papers from 2008: 1) Nagayama, S., Butler, J.T., and Sasao, T., “Programmable Numerical Function Generators for Two-Variable Functions,” *EUROMICRO Conference on Digital System Design (DSD-2008)*, pp.891-898, September 2008; and 2) Nagayama, S., Sasao, T., and Butler, J.T., “Numerical Function Generators using Bilinear Interpolation,” *Proceedings of the IEEE International Conference on Field Programmable Logic and Applications*, pp. 463-466, September 2008.)

[5] Frenzen, C.L., Sasao, T., and Butler, J.T., “On the Number of Segments Needed in a Piecewise Linear Approximation,” *Journal of Computational and Applied Mathematics* (accepted). (There is no previous conference version of this manuscript. Published in electronic form and will be published in print form later.)

[6] Nagayama, S., Sasao, T., and Butler, J.T., “Floating-Point Numeric Function Generators Based on Piecewise-Split EVBDDs,” *Proceedings of the International Symposium on Multiple-Valued Logic*, Barcelona, Spain, 21-23 May 2010 (accepted).

[7] Nagayama, S., Sasao, T., and Butler, J.T., "Systematic Design Method for Two-Variable Numeric Function Generators using Multiple-Valued Decision Diagrams," *IEICE Transactions on Information and Systems*, Col. E93-D, No. 9, August 2010 (submitted: 11 November 2009). (This is an extended version of Nagayama, S. and Sasao, T., "Representations of Two-Variable Elementary Functions using EVMDDs and Their Applications to Function Generators," *Proceedings of the International Symposium. on Multiple-Valued Logic*, Dallas, U.S.A., pp. 50-56, May 22-23, 2008.

PRESENTATION:

Butler, J.T., "Numeric Function Generators," 3rd International Symposium of Information Electronic Systems, Sendai, Japan, 14 July 2009 (invited).

KEYWORDS: Numeric Function Generators, High-Speed Arithmetic Circuits, Piecewise Polynomial Approximation

ROBUST ADAPTIVE-CONTROL WITH EXTERNAL DISTURBANCES AND UNMODELED DYNAMICS

Roberto Cristi, Professor

Department of Electrical and Computer Engineering

Brij N. Agrawal, Distinguished Professor

Department of Mechanical and Aerospace Engineering

Sponsor: National Reconnaissance Office

OBJECTIVE: To develop and evaluate robust adaptive control techniques for accurate pointing and tracking of spacecraft with flexible appendages, external disturbances, and un-modeled dynamics. The main issues are the estimation of the inertia matrix and the need for compensating for vibration effects due to flexible appendages. The proposed controller must guarantee sufficient robustness and "well behaved" response to be deployed in space in an unsupervised environment.

DISSERTATION DIRECTED:

Yang, J.H., "Robust Adaptive Control using a Filtering Action," Ph.D. Dissertation, Naval Postgraduate School, September 2009.

KEYWORDS: Navigation, Control, Estimation

DETECTION OF PSK MODULATED SIGNAL SHIFT TIMING INFORMATION USING THE TEMPORAL CORRELATION FUNCTION

Monique P. Fargues, Professor

Department of Electrical and Computer Engineering

Sponsor: National Security Agency

OBJECTIVE: This work extends earlier work and investigates the use of image processing tools and matched filtering to estimate hopping times occurring in phase hopping communication schemes.

SUMMARY: This project investigated the detection of phase shifts contained within a noisy Phase Shift Keyed modulated signal. The approach derived in this work included image processing techniques including two-dimensional filters, edge detection, morphological processing, and a two-dimensional, cross-correlation, matched filter to detect the phase shifts from the angle of the signal temporal correlation function. Results show the proposed algorithm is robust to additive white noise distortions down to SNR levels of 4 dB.

THESIS DIRECTED:

Kramer, J.E., "PSK Shift Timing Information Detection using Image Processing and a Matched Filter," Master's Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: PSK Signals, Communication Signals

FH DETECTION IN THE PRESENCE OF INTERFERENCES

Monique P. Fargues, Professor

Department of Electrical and Computer Engineering

Sponsor: National Security Agency

SUMMARY: Frequency hopping (FH) communication schemes have received increased attention over the last decades. With increased use comes the risk of interferences degrading decoding performances. A significant body of work has already been conducted mitigating the impact due to narrowband or wideband interferences present in FH schemes. This project proposes to extend previous work conducted by the Naval Postgraduate School by the principal investigator in that field.

INVESTIGATIONS INTO WAVELET OFDM RECEIVER PERFORMANCES

Monique P. Fargues, Professor

Department of Electrical and Computer Engineering

Sponsor: National Security Agency

OBJECTIVE: To investigate wavelet OFDM schemes. First, a thorough review of the literature in that area will be conducted; next, the principal investigators will determine how crucial the exact knowledge to the wavelet information is in resulting demodulation performances.

SUMMARY: A background literature review of the technical area was conducted, and an initial modulator/demodulator was implemented.

KEYWORDS: Wavelet, OFDM Signals, Communication Signals

DEVELOPMENT OF A FORMAL METHOD STRATEGY FOR THE NEXT-GENERATION SECURITY NETWORK SERVER

Douglas J. Fouts, Professor

Department of Electrical and Computer Engineering

George Dinolt, Associate Professor

Department of Computer Science

Sponsor: Boeing Phantom Works

OBJECTIVE: To investigate and evaluate methods for automatic or semiautomatic conversion of C language applications to FPGA implementations. To investigate and evaluate formal methods for automatic or semiautomatic conversion of assured C language applications to assured FPGA implementations. To develop a strategy for developing assured tools for automatic or semiautomatic conversion of assured C language applications to assured FPGA implementations.

SUMMARY: An investigation was conducted and it was determined that there are no tools suitable for this project for automatic conversion of the C language application of interest to an FPGA implementation. Further investigation indicated that there were some tools available that could perform semiautomatic conversion of parts of the C language application of interest to an FPGA implementation. However, a significant human effort would be required. An investigation was conducted and it was determined that none of the tools for semiautomatic conversion of C language applications to FPGA implementations utilized formal methods, nor would the use of any such tools result in an assured conversion, a necessity for

ELECTRICAL AND COMPUTER ENGINEERING

this project. An additional investigation was conducted and it was determined that even if an assured C language application to FPGA implementation conversion could be accomplished, or if a new assured FPGA design was started from scratch, the resulting FPGA implementation would still not be assured because at the present time, there are no available assured FPGA chips in which to implement the design.

KEYWORDS: C to FPGA Conversion, Assured C to FPGA Conversion, Formal Methods for C to FPGA Conversion

THE NATIONAL SECURITY AGENCY/APPLIED TECHNOLOGY DIVISION CRYPTOLOGIC RESEARCH LAB AND THESIS RESEARCH SUPPORT

Tri T. Ha, Professor

Department of Electrical and Computer Engineering

Sponsor: National Security Agency

OBJECTIVE: To support the Cryptologic Research Laboratory at the Naval Postgraduate School wherein graduate students and faculty perform research in support of the National Security Agency's (NSA) Applied Technology Division. This year's research centers on techniques for Doppler correction.

SUMMARY: This research examined the Doppler effect on QAM signals to determine the feasibility of Doppler correction for high mobility operations. The Differential and Double-Differential Decision-Feedback Algorithms were employed with success.

THESIS DIRECTED:

Smith, J., "Doppler Effects on Single-Carrier Signals Operating in Fading Channels," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: Doppler, Algorithm, Mobility

RF EXPLOITATION OF WIRELESS SIGNALS

Tri T. Ha, Professor

Department of Electrical and Computer Engineering

Sponsor: Center for Cyber Warfare, Naval Postgraduate School

OBJECTIVE: To document the procedures of generating various signal formats and then process them using Signalworks for use in lab environments.

SUMMARY: This project examined the process of building test signals within Signalworks and then processing them with the available demodulation applications to define important parameters used to identify and analyze signals. This includes the feasibility of using Signalworks in a lab environment to demonstrate and educate students on signal basics, including wireless communication signals.

THESIS DIRECTED:

Sears, E., "Portable Signals Analysis Solutions using Signalworks: A Process Guide for Analysts and Students," Master's Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: RF, Exploitation, Identification

ELECTRICAL AND COMPUTER ENGINEERING

THE COMMAND WIRE SENSOR

David C. Jenn, Professor

Department of Electrical and Computer Engineering

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To take a first-cut at a design for an active command wire sensor, similar to radar, that could be man-portable and could operate in real time.

SUMMARY: Success in defeating wirelessly detonated improvised explosive devices (IEDs) has resulted in the increased use of command wires and trip wires for triggering explosives. Radar is being investigated as a means of detecting command wires, but radar has many disadvantages. A much simpler radio frequency (RF) sensor can potentially detect the presence of command wires. It would exploit the traveling wave effect that occurs for electromagnetic scattering by long wires. The sensor could be used to detect the presence of buried command wires at a safe distance and at reasonable search rates, and could possibly be made small enough to be man-portable. This research provided a first-cut design and simulation of a proposed command wire sensor system. The sensor performance was determined as a function of several design operational parameters.

PRESENTATION:

Jenn, D., "Command Wire Sensor," JIEDDO Mentor Committee, Naval Postgraduate School, August 2009.

PROJECT REPORT:

Jenn, D., "Command Wire Sensor," JIEDDO Project Report, September 2009.

DEVELOPMENT OF A DIGITAL PHASED ARRAY FOR DEMONSTRATION OF AN RSNS VIRTUAL DIRECTION-FINDING TECHNIQUE

David C. Jenn, Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Information Operations Command-Suitland

SUMMARY: The Naval Postgraduate School (NPS) has demonstrated that the RSNS can efficiently resolve the ambiguities of the phase differentials to achieve high-resolution DF using a short baseline. DF also forms an important branch of electronic intelligence. Low-cost high-resolution arrays are desirable for mobile platforms that are used as stand-in sensors to detect low probability-of-intercept emitters and require an onboard DF system for emitter-system functions.

AN INTEGRATED ANTENNA ELEMENT FOR SHIP APERSTRUCTURES

David C. Jenn, Professor

Department of Electrical and Computer Engineering

Sponsor: Office of Naval Research

OBJECTIVE: To investigate the design and manufacturing issues related to imbedding an array element into a ship structure, i.e., aperstructure. The topics to be addressed include: 1) possible radiating elements that could be integrated into ship deckhouse structure, 2) efficient feeding methods, and 3) fabrication techniques.

ELECTRICAL AND COMPUTER ENGINEERING

WIRELESSLY NETWORKED OPPORTUNISTIC ARRAYS

David C. Jenn, Professor

Department of Electrical and Computer Engineering

Sponsor: National University of Singapore (CRADA)

OBJECTIVE: An opportunistic array is an integrated, platform-wide digital phased array, where elements are placed at available open areas over the entire length of the platform. This phase of the research continued the development of the hardware and techniques to implement the concept. More detailed simulations and hardware studies were performed, resulting in a demonstration design for a 2.4 GHz array.

SUMMARY: The recent research focused on designing and building a demonstration array at 2.4 GHz, taking advantage of low-cost components available at this frequency. The demonstration array has most of the functionality of the full scale system, although the performance was scaled back to save cost. The major purpose of demonstration array was to examine timing and synchronization issues, and to develop controller and signal processing software.

PUBLICATION:

Jenn, D., Loke, Y., Hong, C., Yeo, E., Ong, C., and Yeo, S., "Distributed Phased Arrays and Wireless Beamforming Networks," *International Journal of Distributed Sensor Networks*, Vol. 5, No. 4, p. 283, July 2009.

THESES ADVISED:

Eng, C.H., "Design and Development of an Automated Demodulator Calibration Station," Master's Thesis, Naval Postgraduate School, December 2009.

Tsai, Y.-C., "Development of the Phase Synchronization Circuit for Wirelessly Distributed Digital Phased Array," Master's Thesis, Naval Postgraduate School, September 2009.

A WIRELESSLY NETWORKED OPPORTUNISTIC DIGITAL ARRAY RADAR

David C. Jenn, Professor

Department of Electrical and Computer Engineering

Sponsor: National University of Singapore

OBJECTIVE: To design and analyze an "opportunistic" (randomly distributed) digital phased array for radar. The array is comprised of self-standing transmit-receive (t/r) modules that have no wire connections other than prime power. Time and phase synchronization are done wirelessly, and baseband data is transferred wirelessly between the elements and a central controller. Synchronization is done continuously using a feedback algorithm, so that synchronization is maintained even if the channel between the elements and controller changes. Antenna beams are formed digitally in a computer processor. Radar processing is also performed in the computer processor.

PULSED POWER SUPPLY DESIGN AND ANALYSIS FOR THE RAILGUN

Alexander L. Julian, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: The Naval Postgraduate School (NPS) will support the Navy Railgun Program by providing basic/applied research in the area of pulsed power systems (PPS). From a component level, thyristors and snubbers will be electrically characterized. From a broader system level, NPS will develop a concept for a mobile gun charging system, perform a trade study for a rotating machine PPS, and perform failure mode and effects analysis.

ELECTRICAL AND COMPUTER ENGINEERING

PULSED POWER SUPPLY DESIGN AND ANALYSIS FOR THE RAILGUN

Alexander L. Julian, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Office of Naval Research

OBJECTIVE: To investigate several issues related to the power supply, including battery charging, failure modes and effects analysis, and module electrical-stress characterization.

SUMMARY: A simplified model of the electromechanical behavior of a railgun was developed in order to predict the electrical stress on a solid-state switching power supply. A capacitor-discharge power supply design was designed, and the behavior was predicted using simulations. Of particular interest was predicting the voltage and current stress on the solid-state devices in the power supply and the snubber components selected to protect the solid-state devices.

SOLID-STATE SWITCH SNUBBER DESIGN AND ANALYSIS FOR PULSED POWER

Alexander L. Julian, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Dahlgren Division

SUMMARY: The Naval Postgraduate School (NPS) will support the Navy Railgun Program by providing basic/applied research in the area of pulsed power systems (PPS). From a component level, thyristors and snubbers will be electrically characterized. From a broader system level, NPS will develop a concept for a mobile gun charging system, perform a trade study for a rotating machine PPS, and perform failure mode and effects analysis.

SOLID-STATE SWITCH SNUBBER DESIGN AND ANALYSIS FOR PULSED POWER

Alexander L. Julian, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Office of Naval Research

OBJECTIVE: Solid-state devices are an effective way to discharge capacitor energy into a pulsed power load. When solid state devices are used in series, then care must be taken to ensure that they share voltage statically and dynamically. This project will identify the voltage and current stress on the thyristors, diodes, resistors, and capacitors when the circuit is used to discharge capacitors into a load.

A SYSTEM MODEL OF A TWENTY-FOUR PULSE RECTIFIER FED BY A TWELVE-PHASE TRANSFORMER

Alexander L. Julian, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: DRS Technologies Corp.

OBJECTIVE: To design, analyze, and model a power distribution system for an electric ship.

SUMMARY: Physics-based models were derived to describe the generators, rectifiers, filters, and loads for an electric ship power distribution system.

KEYWORDS: Voltage Source Inverter, Digital Control, Twenty Four Pulse Rectifier

ELECTRICAL AND COMPUTER ENGINEERING

CYBERSECURITY RESEARCH

Jeffrey B. Knorr, Professor

Department of Electrical and Computer Engineering

Sponsor: National Security Agency

OBJECTIVE: To establish a research program in support of the National Cybersecurity Initiative.

BANDWIDTH EFFICIENT MODULATION

Frank E. Kragh, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: National Reconnaissance Office

OBJECTIVE: To explore enhanced, bandwidth-efficient modulation (BEM) schemes emphasizing pulse-shaping filters and pulse-shaping filter design tools. The objective is to devise pulse-shaping filters that are more spectrally efficient than traditional pulse-shaping filters, while offering shift orthogonality, low peak to average power ratio (PAPR), low bit error ratio (BER), and other properties as deemed desirable by the sponsor.

CONSULTING REGARDING THE JOINT TACTICAL RADIO SYSTEM

Frank E. Kragh, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: The Joint Tactical Radio System (JTRS) is the next-generation U.S. military digital radio for field operations. Each JTR is a software-defined radio that will work with many legacy military radio systems. JTRS radios include integrated encryption capabilities and modes that enable high data rate mobile ad hoc networks (MANETs). The objective of this very small project is to advise the sponsor on various technical aspects of the JTRS to support their work in JTRS routing protocols.

SUMMARY: The principle investigator advised the sponsor regarding technical aspects of the JTRS, including physical layer radio communications, software design for transceivers, hardware options, the Software Communications Architecture, and the various JTRS waveforms and radio form factors. This took the form of technical advisement in person in Monterey, California, and via telephone.

PUBLICATION:

Gonzalez, C., Dietrich, C., Kragh, F., Sayed, S., Volos, H., Gaeddert, J., et al., "Open-Source SCA-Based Core Framework and Rapid Development Tools Enable Software-Defined Radio Education and Research," *IEEE Communications Magazine*, Vol. 47, No. 10, October 2009.

KEYWORDS: CubeSat, Satellite Design, Satellite Communications

ENGINEERING SMALL SATELLITES FOR SPACE-BASED EXPERIMENTS

Frank E. Kragh, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Secretary of the Air Force/FMBMB-AFOY

OBJECTIVE: To explore a wide range of technical aspects of small satellite design, including payload design, attitude control, deployment techniques, command and telemetry, data handling and communications, electrical power, thermal control, software design, and hardware design. Experiment requirements were mapped into satellite functions and satellite subsystems, including possibilities to consider for the engineering of each subsystem.

SUMMARY: Space experiments are often extremely expensive due to the costs of launching the experimental satellite and the non-recurring engineering costs of its design. The CubeSat Program, begun by CalPoly San Luis Obispo and Stanford, is an effort to reduce those costs for satellites with modest requirements. This program has developed a standardized small-satellite design that is intended to be easily integrated into a much larger launch vehicle and deployed at the appropriate orbital altitude. CubeSats are 10 cm × 10 cm × 10 cm cubes, or a combination of such cubes (three combined is common), that conform to the “CubeSat standard.” CubeSat kits are inexpensive (\$6K each) and include the cubic metal frame, a low power micro-controller, a development board and flight module, transceiver interfaces, and a real-time operating system (RTOS). This provides the framework on which to add an experimental payload.

The radio communications portion of the CY2009 research revealed that one of the sponsor’s desired options for solution was not feasible due to inefficient demodulation. An alternate demodulation algorithm was proposed that made the communications feasible yet required approximately 30 dB less transmit power.

For the optical communications portion of research in this calendar year, a CRADA was formed with a company producing modulating retro-reflectors, and the test laboratory was equipped and set up.

Late in FY09, the sponsor reported that the desired option we found technically infeasible was the only option their organization could accept, for non-technical reasons unrelated to this research. Since this option had already been shown to be infeasible, the sponsor cancelled the program.

KEYWORDS: CubeSat, Satellite Design, Satellite Communications

CONFIGURABLE FAULT-TOLERANT ARCHITECTURES FOR RELIABLE SPACE-BASED COMPUTING

Herschel H. Loomis, Professor
Department of Electrical and Computer Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: This project is concerned with the application of fault-tolerant techniques to reconfigurable, space-based digital processors, with computer algorithms to specific military space projects, the development of specialized computer architectures for military space applications, and the infusion of the research into the field.

FAULT-TOLERANT TECHNIQUES AS APPLIED TO RECONFIGURABLE ARCHITECTURES (CFTP – SPONSOR 1)

Herschel H. Loomis, Professor
Department of Electrical and Computer Engineering
Sponsor: Secretary of the Air Force/FMBIB-AFOY

OBJECTIVE: To demonstrate the value of the remote reconfigurability of field-programmable gate arrays to space computing.

FAULT-TOLERANT TECHNIQUES AS APPLIED TO RECONFIGURABLE ARCHITECTURES (CFTP – TESTING)

Herschel H. Loomis, Professor
Department of Electrical and Computer Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To test a new fault-tolerant technique on the configurable fault-tolerant architectures for reliable, space-based computing.

ELECTRICAL AND COMPUTER ENGINEERING

MDA: MULTI-SOURCE FUSION AND CORRELATION

Herschel H. Loomis, Professor

Alan A. Ross, Professor of the Practice

Department of Electrical and Computer Engineering

Sponsor: Naval Postgraduate School

OBJECTIVE: To develop a toolset for data manipulation, fusion, and display, and thus to demonstrate improved maritime domain awareness.

RELIABILITY ENHANCEMENT OF THE OPERA MULTIPROCESSOR ARCHITECTURE

Herschel H. Loomis, Professor

Department of Electrical and Computer Engineering

Sponsor: Secretary of the Air Force

OBJECTIVE: To study the fault tolerance of the On-Board Processing Expandable Reconfigurable Architecture.

BOTNET AND DNS DEVELOPMENT

John C. McEachen, Professor

Murali Tummala, Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Information Operations Command-Suitland

OBJECTIVE: To study the propagation of bots into a Botnet and the various malicious activities that could be carried out from within a tactical network, which pose a significant threat to network security and tactical operations.

SUMMARY: A network architecture with the objective of near real-time detection of malicious activity and its propagation within a data rate limited environment with periodic losses of connectivity without adding significant burden to the network was proposed. A testbed was constructed that makes use of an intrusion-detection-system driven correlation tool, BotHunter, focused on outbound and inbound connections, rather than solely on inbound connections and a honeynet located in a high data rate area of a tactical network. The ability of the proposed architecture to identify malicious activities was validated when both BotHunter and the honeynet successfully detected a bot infection.

PRESENTATIONS:

McEachen, J.C., "Botnets and Botnet Detection," presented to NIOC Representatives, May 2009.

McEachen, J.C., "ECE Cyber Warfare Research," presented to Mr. Will Janssen, Director, Systems Network Attack Center, National Security Agency, Monterey, California, 24 April 2009.

McEachen, J.C., "Initiatives in Cyber Warfare," presented to Lt.Gen. James Clapper, Undersecretary of Defense – Intelligence, USD(I), Monterey, California, 11 September 2009.

McEachen, J.C., "Initiatives in Cyber Warfare," IC/SPECOPS Consortium, Seaside, California, 10 February 2009.

THESIS DIRECTED:

Becker, R., "A Test Bed for Detection of Botnet Infections in Low Data Rate Tactical Networks," Master's Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: Botnets, Tactical Networks, Network Security, Malware, Cyber Networks, Intrusion Detection, Honeynet, Honeybot

GEOLOCATION OF WiMAX/4G MOBILE DEVICES

John C. McEachen, Professor

Murali Tummala, Professor

Department of Electrical and Computer Engineering

Sponsor: National Reconnaissance Office

OBJECTIVE: WiMAX is an emerging technology for metropolitan-area, high data-rate access. It is considered the leading contender for 4G mobile phone adoption. This was recently backed by a \$3.2B investment by a consortium of Intel, Google, Sprint, and others. The objective of this new research is to develop precision geolocation techniques based on control messages used by WiMAX base-stations and subscribers. This will be done through an analysis of traditional geolocation techniques and modification of the computational constraints to incorporate the WiMAX control information. This approach leverages prior knowledge of mobile phone geolocation with new knowledge of the WiMAX signal. Validation will be conducted through simulation of the WiMAX intercept under a variety of conditions.

SUMMARY: The possibility of geolocating a WiMAX subscriber station based on the timing-adjust ranging parameter within the network signal internals was investigated. The basic approach to geolocation based on radial distances from multiple base stations was outlined. Specifics of the timing parameters used during WiMAX network entry were examined as they relate to calculating these distances. Laboratory testing demonstrated successful capture of ranging parameters from the air interface, leading to the development of a web-based geolocation tool to map likely locations of subscriber stations. Field collection of the air interface from a single base-station network verified a high correlation with low variance when comparing values in timing-adjust values in packets exchanged during network entry. Using field test results, computer simulation further refined the expected geolocation accuracy in multiple base-station networks. Results showed the possibility of fixes with 10 times greater accuracy than in previous results in literature applying timing advance techniques to Global System for Mobile Communications networks.

PRESENTATIONS:

Barber, D.E., "Geolocation of WiMAX," presented to NRO AS&T representatives, Monterey, California, 2 December 2009.

Barber, D.E. and McEachen, J.C., "Geolocation of WiMAX," presented to NRO AS&T representatives, Monterey, California, 20 May 2009.

Garcia, V.C. and McEachen, J.C., "Cross-Community Collaboration for Cyber," Worldwide Overhead Conference, Aurora, Colorado, 17 September 2009.

McEachen, J.C., "Security Issues in Future Telephony: VoIP and 4G Mobiles," Cybersecurity Awareness Month Brown Bag Seminar, Monterey, California, 22 October 2009.

McEachen, J.C., "Threat Level Orange – How Much Can You Count on Your Wireless Mobile Device?" NPS Cyber Summit, Monterey, California, 29 October 2009.

McEachen, J.C., Barber, D.E., and Licklider, D., "Future Mobile Devices and WiMAX," Classified Advanced Technical Update, Monterey, California, 29 July 2009.

THESIS DIRECTED:

Barber, D.E., "Geolocation of WiMAX Subscriber Stations Based on the Timing Adjust Ranging Parameter," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: WiMAX, 4G, Mobile Devices, Wireless Networks, Geolocation

JOINT THREAT WARNING SYSTEM FY09 THREAT SIGNALS PROJECTION AND RESEARCH

John C. McEachen, Professor

Weilian Su, Assistant Professor

Murali Tummala, Professor

Department of Electrical and Computer Engineering

Sponsor: U.S. Special Operations Command

OBJECTIVE: To support the Joint Threat Warning System (JTWS) program.

SUMMARY: Research conducted under this project includes developing new distributed direction finding and geolocation algorithms, integrating techniques in computer network operations into SOF operational systems, and investigating efforts with wireless sensor and SMART Dust programs for integration into SOF operational systems.

KEYWORDS: Sensor Networks, Geolocation, JTWS

JOINT THREAT WARNING SYSTEM THREAT SIGNALS PROJECTION AND RESEARCH

John C. McEachen, Professor

Murali Tummala, Professor

Weilian Su, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Space and Warfare Systems Command–Space Systems Center Charleston

OBJECTIVE: To support the Joint Threat Warning System (JTWS) program. This will include providing an assessment of future technologies and threats for defining SOF SIGINT requirements, developing new distributed direction finding and geolocation algorithms for applications to JTWS, including leveraging algorithms of the Cryptologic Research Laboratory for analysis of signals of interest to USSOCOM, integrating techniques in computer network operations into SOF operational systems, and investigating efforts with wireless sensor and SMART Dust programs for integration into SOF operational systems.

SUMMARY: This research had the following primary areas of focus:

- Investigate efforts with SMART Dust programs for integration into the JTWS Component Architecture Framework (JCAF).
- Integrate techniques in computer network operations into JCAF.
- Assess future technologies and threats for defining SOF SIGINT requirements.
- Leverage algorithms of the Communications Research Laboratory for analysis of signals of interest to SOCOM.

This effort expanded the charter of the SOF Multimission Advanced Research and Technology (SMART) forum to allow research relevant to SOF Multimission SIGINT operations to be presented in a common forum. This effort also examined SMART Dust technologies-related issues, such as efficient medium access and its applications to beamforming for source localization and the procedure to bring them into conformance with JCAF. Specifically, a scheme for the low power and low probability-of-detection (LPPD) denial-of-service against a fixed WiMAX communication system was developed. The initial ranging contention window was exploited as a single point-of-failure for network entry in a WiMAX network. A scheme using cyclostationary spectral analysis for the identification and classification of OFDM was investigated. The preamble, cyclic prefix, and pilot subcarriers of the WiMAX and WiFi network waveforms were successfully identified. Additionally, cognitive radio technologies were explored. A spectrum sensing and localization scheme using a radio frequency sensor network was developed. The

proposed sensor-network-based cooperative wideband spectrum sensing and localization uses wavelet-based multi-resolution spectrum sensing and received signal strength-based localization methods.

PUBLICATIONS:

Childers, T., Poh, Y.T., McEachen, J., and Tummala, M., "A Model for Virtual Physical Layer Communication over Deployed Wireless Sensor Networks," *International Conference on Signal Processing and Communication Systems*, Omaha, Nebraska, 28-30 September 2009.

Lintz, W.A., McEachen, J., and Tummala, M., "A Method for Determining Weight Reset Timing in a Wirelessly Networked Array with Independently Mobile Elements," *Proceedings of the International Conference on Advanced Information Networking and Applications (AINA '09)*, pp. 914-920, 26-29 May 2009.

Lintz, W.A., McEachen, J., and Tummala, M., "Sensor Beamforming with Distributed Mobile Elements in a Wireless Sensor Network," *Proceedings of the Canadian Conference on Electrical and Computer Engineering (CCECE '09)*, pp. 323-328, 3-6 May 2009.

Walker, T.O., Tummala, M., and McEachen, J., "Energy-Efficient, Flow-Specific Medium Access using Preamble Sampling," *International Conference on Signal Processing and Communication Systems*, Omaha, Nebraska, 28-30 September 2009.

Walker, T.O., Tummala, M., and McEachen, J., "Performance Analysis of Slotted ALOHA with Periodic Server Vacations for Energy-Efficient Medium Access," *Forty-Second Asilomar Conference on Signals, Systems, and Computers*, Monterey, California, November 2009.

Walker, T.O., Tummala, M., and McEachen, J., "Traffic-Adaptive, Flow-Specific, Medium Access Control for Wireless Networks," *Proceedings of the IEEE Wireless Communications and Networking Conference*, pp. 1-6, Budapest, Hungary, 5-8 April 2009.

PRESENTATIONS:

McEachen, J.C., "ECE Cyber Warfare Research," presented to RADM Mike Brown, Deputy Assistant Secretary for Cybersecurity and Communications, Monterey, California, 20 November 2009.

McEachen, J.C., "ECE Cyber Warfare Research," presented to CAPT Gene Potente, OPNAV N6F5, Monterey, California, 28 October 2009.

McEachen, J.C., "Initiatives in Cyber Warfare," presented to Lt.Gen. James Clapper, Undersecretary of Defense – Intelligence, USD(I), Monterey, California, 11 September 2009.

McEachen, J.C., "Initiatives in Cyber Warfare," IC/SPECOPS Consortium, Seaside, California, 10 February 2009.

McEachen, J.C., "Initiatives in Cyber Warfare," JSOC representatives, Monterey, California, 30 September 2009.

McEachen, J.C., "NPS Cyber Warfare Research," DoD Emerging Cyber S&T Needs Workshop, Wright Patterson Air Force Base, Dayton, Ohio, 18 November 2009.

McEachen, J.C., "NPS Research in Support of JTWS," Joint Threat Warning System (JTWS) Program Management Review, Tampa, Florida, 8 December 2009.

McEachen, J.C., "Security Issues in Future Telephony: VoIP and 4G Mobiles," Cybersecurity Awareness Month Brown Bag seminar, Monterey, California, 22 October 2009.

ELECTRICAL AND COMPUTER ENGINEERING

McEachen, J.C., "Threat Level Orange – How Much Can You Count on Your Wireless Mobile Device?" NPS Cyber Summit, Monterey, California, 29 October 2009.

McEachen, J.C., Tummala, M., Walker, O., and Su, W., "Tutorial: Applications of Wireless Sensor Networks," IEEE Hawaii International Conference on Systems Sciences, 5 January 2009.

THESES DIRECTED:

Childers, T.E., "File Transfer with Erasure Coding Over Wireless Sensor Networks," Master's Thesis, Naval Postgraduate School, March 2009.

Licklider, D.O., "Low Power, Low-Probability-of-Detection Denial of Service against IEEE 802.16 Communications Systems," Master's Thesis, Naval Postgraduate School, September 2009.

Lintz, W.A., "Radio Frequency Signal Reception via Distributed Wirelessly Networked Sensors under Random Motion," Ph.D. Dissertation, Naval Postgraduate School, September 2009.

McGee, J.B., "Sharing of Position Location Information on Time Division Multiple Access Mobile Ad Hoc Wireless Networks," Master's Thesis, Naval Postgraduate School, March 2009.

Schnur, S.R., "Identification and Classification of OFDM-Based Signals using Preamble Correlation and Cyclostationary Extraction," Master's Thesis, Naval Postgraduate School, September 2009.

Sonmezer, V., "Cooperative Wideband Spectrum Sensing and Localization for RF Sensor Networks," Master's Thesis, Naval Postgraduate School, September 2009.

Tsivgoulis, G., "Source Localization in Wireless Sensor Networks with Randomly Distributed Elements under Multipath Propagation Conditions," Master's Thesis, Naval Postgraduate School, March 2009.

Walker, T.O., "Traffic-Adaptive, Flow-Specific, Medium Access for Wireless Networks," Ph.D. Dissertation, Naval Postgraduate School, September 2009.

KEYWORDS: SIGINT, Signal Identification, WiMAX, Denial of Service, Special Operations Forces, Smart Dust, Sensor Networking, Traffic Adaptive Medium Access, Spectrum Sensing, Source Localization

SOF MULTI-MISSION ADVANCED RESEARCH

John C. McEachen, Professor

Weilian Su, Assistant Professor

Murali Tummala, Professor

Department of Electrical and Computer Engineering

Sponsor: SPAWAR-Charleston

OBJECTIVE: To develop protocols and techniques for ad hoc networks and wide area networks.

SUMMARY: Research conducted under this project included sensor networks and wide area networks.

PUBLICATIONS:

Su, W. and Alzaghal, M., "Channel Propagation Characteristics of Wireless MICAz Sensor Nodes," *Ad Hoc Networks (Elsevier) Journal*, Vol. 7, Iss. 6, pp. 1183-1193, April 2009.

Su, W. and Lim, T.L., "Cross-Layer Design and Optimization for Wireless Sensor Networks," *International Journal of Sensor Networks*, Vol. 6, No. 1, pp. 3-12, 2009.

THESIS DIRECTED:

Simsek, K., "Developing a Capacitance Readout Circuitry for a Directional MEMS Sound Sensor and Sound Source Localization in a Sensor Network Environment," Master's Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Sensor Networks, SIGINT/IW System, Wide Area Networks

SOF MULTI-MISSION ADVANCED RESEARCH AND TECHNOLOGY JOINT THREAT WARNING SYSTEM RESEARCH, DEVELOPMENT, TEST, AND EVALUATION

John C. McEachen, Professor

Department of Electrical and Computer Engineering

Sponsor: Space and Naval Warfare Systems Center-Charleston

OBJECTIVE: To support the Joint Threat Warning System (JTWS) Program. This will include investigating integration of SMART Dust technology into the JTWS Component Architecture Framework (JCAF), investigations into integrating computer network operations into lightweight SOF SIGINT systems, and classified signals analysis.

SOF MULTI-MISSION SIGINT SUPPORT TO JOINT THREAT WARNING SYSTEM RESEARCH, DEVELOPMENT, TEST, AND EVALUATION

John C. McEachen, Professor

Murali Tummala, Professor

Weilian Su, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Space and Warfare Systems Command-Space Systems Center Charleston

OBJECTIVE: To support the Joint Threat Warning System (JTWS) Program. This will include investigating integration of SMART Dust technology into the JTWS Component Architecture Framework (JCAF), investigations into integrating computer network operations into lightweight SOF SIGINT ground and UAV systems, and classified signals analysis.

SUMMARY: This research had the following primary areas of focus:

- Investigate efforts with SMART Dust programs for integration into the JTWS Component Architecture Framework (JCAF).
- Integrate techniques in computer network operations into JCAF.
- Assess future technologies and threats for defining SOF SIGINT requirements.
- Leverage algorithms of the Communications Research Laboratory for analysis of signals of interest to SOCOM.

This effort expanded the charter of the SOF Multimission Advanced Research and Technology (SMART) forum to allow research relevant to SOF Multimission SIGINT operations to be presented in a common forum. This effort also examined SMART Dust technologies, such as WOLFPACK, and the procedure to bring them into conformance with JCAF. Specifically, an interface was developed for prioritizing and forwarding sensor information. The Communication Research Laboratory investigated signals processing techniques of interest to SOCOM and provided recommendations as to avenues for follow-on pursuit. Methods for distributed beamforming and direction finding for application to JTWS systems, such as the GSK and TT, were investigated. Further investigations into efficient medium access methods for wireless sensor and Smart Dust programs and their integration into JTWS were conducted. Also, techniques for fusion of sensor data in JTWS were studied.

PUBLICATIONS:

Childers, T., Poh, Y.T., McEachen, J., and Tummala, M., "A Model for Virtual Physical Layer Communication over Deployed Wireless Sensor Networks," *International Conference on Signal Processing and Communication Systems*, Omaha, Nebraska, 28-30 September 2009.

Lintz, W.A. and McEachen, J.C., "A Method for Emphasizing Signal Detection in Wireless Sensor Network Radio Frequency Array Operation," *42nd Hawaii International Conference on System Sciences, 2009, HICSS '09*, pp. 1-10, January 2009.

Lintz, W.A., McEachen, J.C., and Jenn, D.C., "Sensor Network Pair-Wise Wireless Communications Performance with Unsteady Node Orientation," *Sarnoff Symposium*, Princeton, New Jersey, April 2009.

Lintz, W.A., McEachen, J., and Tummala, M., "A Method for Determining Weight Reset Timing in a Wirelessly Networked Array with Independently Mobile Elements," *Proceedings of the International Conference on Advanced Information Networking and Applications (AINA '09)*, pp. 914-920, 26-29 May 2009.

Lintz, W.A., McEachen, J., and Tummala, M., "Sensor Beamforming with Distributed Mobile Elements in a Wireless Sensor Network," *Proceedings of the Canadian Conference on Electrical and Computer Engineering (CCECE '09)*, pp. 323-328, 3-6 May 2009.

Walker, T.O., Tummala, M., and McEachen, J., "Energy-Efficient, Flow-Specific Medium Access using Preamble Sampling," *International Conference on Signal Processing and Communication Systems*, Omaha, Nebraska, 28-30 September 2009.

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PRESENTATIONS:

McEachen, J.C., "Initiatives in Cyber Warfare," IC/SPECOPS Consortium, Seaside, California, 10 February 2009.

McEachen, J.C., "Initiatives in Cyber Warfare," JSOC Representatives, Monterey, California, 30 September 2009.

McEachen, J.C., "NPS Initiatives SOF in Wireless Networking Operations," Joint Threat Warning System (JTWS) Program Management Review, Tampa, Florida, 3 December 2008.

McEachen, J.C., Tummala, M., Walker, O., and Su, W., "Tutorial: Applications of Wireless Sensor Networks," *IEEE Hawaii International Conference on Systems Sciences*, 5 January 2009.

THESES DIRECTED:

Childers, T.E., "File Transfer with Erasure Coding Over Wireless Sensor Networks," Master's Thesis, Naval Postgraduate School, March 2009.

Lintz, W.A., "Radio Frequency Signal Reception via Distributed Wirelessly Networked Sensors under Random Motion," Ph.D. Dissertation, Naval Postgraduate School, September 2009.

Tsivgoulis, G., "Source Localization in Wireless Sensor Networks with Randomly Distributed Elements under Multipath Propagation Conditions," Master's Thesis, Naval Postgraduate School, March 2009.

Walker, T.O., "Traffic-Adaptive, Flow-Specific, Medium Access for Wireless Networks," Ph.D. Dissertation, Naval Postgraduate School, September 2009.

KEYWORDS: SIGINT, Special Operations Forces, Smart Dust, Sensor Networking, High Speed Networking

VULNERABILITIES IN VOIP COMMUNICATIONS

John C. McEachen, Professor

Murali Tummala, Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Information Operations Command-Suitland

OBJECTIVE: To evaluate IO vulnerabilities in VoIP software algorithms and associated protocols, which, if exploited by a potential adversary, could threaten Department of Defense (DoD) VoIP networks. Vulnerabilities in both the SIP and H.323 protocols were examined for issues in redirection, replay, insertion, and denial of service.

SUMMARY: Several areas of vulnerabilities were identified. One in particular that was common to all VoIP technologies was related to the Real Time Transport Protocol (RTP). The RTP has no checksum and consequently, it is possible to modify the RTP payload without being observed. This could potentially facilitate content replacement and insertion. Additional RTP vulnerabilities were identified and evaluated. A prototype was developed for follow-on demonstrations and evaluations.

PRESENTATION:

McEachen, J.C., "Security Issues in Future Telephony: VoIP and 4G Mobiles," Cybersecurity Awareness Month Brown Bag Seminar, Monterey, California, 22 October 2009.

THESES DIRECTED:

Stence, P., "Exploitation of Real Time Transport Protocol Susceptibility to External Interference with Regard to Voice over Internet Protocol," Master of Science in Electrical Engineering, Master's Thesis, Naval Postgraduate School, September 2009.

Turner, A., "An Applications Programmer Interface for Content Insertion in Real Time Transport Protocol," Master's Thesis, Naval Postgraduate School, (in progress).

KEYWORDS: SIGINT, VoIP, RTP, SIP, H.323

WIRELESS NETWORKING

John C. McEachen, Professor

Murali Tummala, Professor

Department of Electrical and Computer Engineering

Sponsor: National Security Agency

OBJECTIVE: To conduct research into modern, digital-radio networks. Specifically, the effort intends to improve upon power consumption in specific radio implementations. Several aspects of this proposal are classified.

SUMMARY: The specific system on a chip implementation was evaluated. Power consumption in the device is a primary concern from a mobile operations point of view. This project evaluated an adaptive

transmission protocol (ATP) which was written into the original firmware as a means of power savings through transmit power and data rate manipulation. The original ATP version maintained a constant transmit power with a variable data rate. Preliminary evaluation of an ATP variation with variable transmit power and data rate showed that the system on chip is able to maintain a constant, albeit lower, data rate across a wider range of channel conditions with a significantly lower energy per kilobit transmitted. Efficient medium access techniques were investigated. Studies on delay tolerant networks and channel assignment were initiated.

CONFERENCE PUBLICATIONS:

Walker, T.O., Tummala, M., and McEachen, J., "Energy-Efficient, Flow-Specific Medium Access using Preamble Sampling," *International Conference on signal Processing and Communication Systems*, Omaha, Nebraska, 28-30 September 2009.

Walker, T.O., Tummala, M., and McEachen, J., "Performance Analysis of Slotted ALOHA with Periodic Server Vacations for Energy-Efficient Medium Access," *Forty-Second Asilomar Conference on Signals, Systems, and Computers*, Monterey, California, November 2009.

PRESENTATION:

Harley, P., Sullivan, B., and McEachen, J.C., "Advances in Delay Tolerant Networking," presented to Dr. Floyd B. Cole, III, Special Projects Director, Research Directorate, National Security Agency, Monterey, California, 9 November 2009.

THESES DIRECTED:

Harley, P., "Implementation and Performance Evaluation of Delay Tolerant Networks," Master's Thesis, Naval Postgraduate School, September 2009.

McGee, J.B., "Sharing of Position-Location Information (PLI) on Time-Division, Multiple-Access (TDMA), Mobile, Ad-Hoc, Wireless Networks," Master's Thesis, Naval Postgraduate School, March 2009.

KEYWORDS: SIGINT, Mesh Networking, Adaptive Transmission

THE APPLICATION AND MEASUREMENT OF ADVANCED, FORMAL, INDEPENDENT VERIFICATION AND VALIDATION TECHNIQUES

James Bret Michael, Professor

Thomas W. Otani, Associate Professor

Man-Tak Shing, Associate Professor

Department of Computer Science

Sponsor: National Aeronautics and Space Administration

OBJECTIVE: To assist the NASA Independent Verification and Validation (IV&V) Facility in the application and measurement of advanced, formal, IV&V techniques.

SUMMARY: This is a continuation of research that commenced in 2007. In fiscal years 2007 and 2008, the principal investigators (PIs) investigated why, in spite of three decades of software formal verification and validation (FV&V) research, there exists no ideal FV&V technique that works well for all FV&V concerns; that is, there is no one technique that enables i) easy and correct construction of requirement specifications of complex, real-world properties of systems, and ii) complete verification coverage of complete, real-life, complex software with respect to those requirements. The PIs developed a framework for augmenting IV&V of software systems with computer-based IV&V techniques. The purpose of the framework is to amenable the IV&V team to capture its own understanding of the application and the expected behavior of any proposed system for solving the underlying problem by using an executable system reference model (SRM), which uses formal assertions to specify mission- and safety-critical

behaviors. In 2009, the PIs focused on the application of reuse to increase the effectiveness and productivity of the IV&V process, techniques for the V&V of software architectures, and the use of metrics to validate software-safety requirements.

The PIs continued work on the use of libraries of assertions to reduce the unnecessary rewriting or incorrect specification of assertions, and developed a framework for reusing all the artifacts in the SRM framework. As is the case for general software reuse, three potential benefits for the reuse of the SR are anticipated: 1) an improved quality of the final product, 2) faster time-to-market development, and 3) reduced development cost. Two types of SRM reuse are anticipated. The first type of reuse is an adoption reuse in which an existing artifact, such as the class diagram or an activity diagram, is copied and used in another product. An artifact can be adopted as is or with a minor modification. The second type of reuse is an instantiation reuse in which a concrete artifact is created from a generic template. In 2008, the PIs developed a framework for instantiation reuse in which the modelers create concrete assertions and test scenarios from the assertion patterns and validation-test scenario patterns stored in the reuse library. In 2009, the framework was extended to other types of SRM artifacts, such as class diagrams, sequence diagrams, and activity diagrams. This work was presented at the 2009 IEEE International Conference on System of Systems Engineering and the 3rd NASA IV&V Workshop on Validation and Verification.

Software architecture plays a vital role in the systematic construction of large systems of systems; it defines the design space and provides a roadmap leading to the successful construction of systems of systems that meet the functional and non-functional requirements. Moreover, a good architecture must allow the system of systems to evolve to meet new requirements due to such things as changes in mission or concept of operations. As software architecture plays an increasingly important role in determining the dependability and trustworthiness of large-scale systems, it is important to include V&V of software architecture as an essential element of system development. Although researchers have developed many methods to analyze software architectures with the goal of identifying risks and predicting the quality of the software system before it is built, the meaning of the V&V of software architecture has never been formally defined, begging the question “what role will these architecture-evaluation methods play in the V&V of software architecture?” In 2009, the PIs developed a mathematical model that ties the non-functional requirements of a software system to its architecture and provides formal definitions for the V&V of software architecture, and an approach to evaluate the quality of software architecture in light of meeting the requirements. This work was presented at the 2009 IEEE International Conference on System of Systems Engineering.

Dependability for a computing system is defined by a set of system qualities (or non-functional requirements) that consists of reliability (continuity of correct service), availability (readiness for correct service), maintainability (the ease to undergo modifications and repairs), safety (absence of catastrophic consequences on the user(s) and the environment), and security (confidentiality and integrity). According to a recent report by the National Research Council’s Committee on Certifiably Dependable Software Systems (“Software for Dependable Systems: Sufficient Evidence?” D. Jackson, M. Thomas, and L.I. Millett (Eds.), Washington, D.C.: The National Academies Press, 2007), “dependability is not a local property of software that can be determined module by module but has to be articulated and evaluated from a systems perspective that takes into account the context of usage. A system may be dependable even though some of its functions fail repeatedly; conversely, it may be regarded as undependable if it causes unexpected effects in its environment, even if it suffers no obvious failures.” It is essential to spell out the expected dependability attributes explicitly, in quantifiable terms. Some of these qualities, like reliability, availability, and maintainability, can be quantified and measured directly. (For example, IEEE Std. 982.1-2005 provides a set of metrics for measuring the reliability, availability, and maintainability of a software system.) Other qualities, like safety and security, cannot be measured directly and can only be defined via a dependability case. For example, the stakeholder requirements and expectations of a safety-critical system are simply that “the system is safe, that is it does not cause unintended harm to people.” The ultimate goal of validation of software safety is to validate the safety requirements. However, because of the lack of stakeholder definition of what constitutes a safe system, the traditional validation model of matching system specification to stakeholder requirements and expectations does not cater to software safety. The PIs developed a new model for validation of software safety requirements via proxies and a metric framework for validation of safety-critical software-intensive systems and system of systems. Application of the framework to a representative, safety-critical, software-intensive system shows that the resulting metric data from the framework can be used as a tool to indicate the validity of software safety requirements. Instead of relying on final testing to reveal any validity issues with software safety requirements,

application of the framework helps to identify potential problems early on in the development lifecycle. While the intellectual process of validating software safety requirements cannot be replaced entirely with metrics, the validation method presented in this paper will engender a more proactive approach to ensuring that the correct software behaviors are identified and implemented to achieve the desired level of system safety. This work was presented at the 2009 IEEE International Conference on System of Systems Engineering and the 3rd NASA IV&V Workshop on Validation and Verification.

In addition, the PIs continued to assist the NASA IV&V Facility in the application of advanced formal IV&V techniques via participation in the Reuse Tiger Team and Dependability Tiger Team, the Lunar Surface Systems Software Workshop, and the development of training materials.

PUBLICATIONS:

Cruickshank, K., Michael, B., and Shing, M., "A Validation Metrics Framework for Safety-Critical Software-Intensive Systems," *Proceedings of the 2009 IEEE International Conference on System of Systems Engineering*, Albuquerque, New Mexico, 1-3 June 2009.

Meacham, D., Michael, B., Shing, M., and Voas, J., "Standards Interoperability: Applying Software Safety Assurance Standards to the Evolution of Legacy Software," *Proceedings of the 2009 IEEE International Conference on System of Systems Engineering*, Albuquerque, New Mexico, 1-3 June 2009.

Michael, B., Riehle, R., and Shing, M., "The Verification and Validation of Software Architecture for Systems of Systems," *Proceedings of the 2009 IEEE International Conference on System of Systems Engineering*, Albuquerque, New Mexico, 1-3 June 2009.

Otani, T., Michael, B., and Shing, M., "Software Reuse in the IV&V of System of Systems," *Proceedings of the 2009 IEEE International Conference on System of Systems Engineering*, Albuquerque, New Mexico, 1-3 June 2009.

PRESENTATIONS:

Michael, J.B., "Building Predictable Behavior into a System of Systems," IEEE Reliability Symposium on Developing Highly Reliable and Trustworthy Products and Systems, University of Texas at Dallas, 23 January 2009.

Michael, J.B., "Computer-Aided Formal Verification and Validation," half-day tutorial presented in conjunction with the IEEE/IFIP International Symposium on Rapid System Prototyping, Paris, France, 23 June 2009.

Otani, T.W., "Reusing Modeling Elements in IV&V," 3rd NASA IV&V Workshop on Validation and Verification, Fairmont, West Virginia, 15-17 September 2009.

Shing, M., "Validating Dependability and Safety Requirements," 3rd NASA IV&V Workshop on Validation and Verification, Fairmont, West Virginia, 15-17 September 2009.

THESIS DIRECTED:

Cruickshank, K.J., "A Validation Metrics Framework for Safety-Critical Software-Intensive Systems," Master's Thesis, Naval Postgraduate School, March 2009.

ELECTRICAL AND COMPUTER ENGINEERING

MODELING, DESIGN, AND OPTIMIZATION OF MULTI-JUNCTION SOLAR CELLS USING SILVACO VIRTUAL WAFER FABRICATION SOFTWARE

Sherif N. Michael, Professor

Department of Electrical and Computer Engineering

Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: To develop advanced models of multi-junction solar cells, using Silvaco Software, along with developing a radiation model for these cells. Radiation effects on advanced cell models will also be investigated and compared with experimental results conducted using the Naval Postgraduate School LINAC.

A new method is proposed for developing a realistic model of any type of solar cell using the Silvaco/ATLAS Virtual Wafer Fabrication Software. This novel methodology is proposed in consideration of the high cost of research and experimentation involved with the development of advanced cells. The introduction of this modeling technique to the photovoltaic community will prove to be of great importance in aiding the design and development of advanced solar cells.

SUMMARY: A multi-junction InGaP/GaAs solar cell was successfully modeled and fully simulated. The major stages of the process were explained, and the simulation results were compared to published experimental data. The flexibility of the proposed methodology was demonstrated, and example results throughout the whole process were presented. Further research for the development of more accurate models that can be used for the design and optimization of advanced multi-junction cells was also investigated.

CONFERENCE PUBLICATIONS:

Michael, S., "A Classified Paper on State-of-the-Art Solar Cells," *Proceedings of the 2009 Annual Solar Arrays and Batteries Conference*, Chantilly, Virginia, 23-25 June 2009.

Michael, S., "Modeling the Effects of Electron Radiation in Solar Cells using Silvaco's ATLAS Software," *Proceedings of the 2009 IEEE Nuclear and Space Radiation Effects Conference*, Quebec City, Canada, 20-24 July 2009.

KEYWORDS: Space Radiation Effects, Satellites, Simulation, Spacecraft Power

RADIATION-TOLERANT ASIC AND VLSI DEVICES FOR SPACE-BASED SYSTEMS

Sherif N. Michael, Professor

Department of Electrical and Computer Engineering

Sponsor: Secretary of the Air Force

OBJECTIVE: To design radiation-tolerant, mixed-mode, VLSI and ASIC circuits for space applications. To fabricate these design after extensive simulation using a regular silicon process as a first step. To study the space radiation effects on these state-of-the-art designs using the Naval Postgraduate School (NPS) LINAC as a radiation source. Upon verification of the experimental results, the layout will be submitted for future fabrication using the SOI process.

SUMMARY: In this research, a general-purpose, digitally programmable, VLSI network for a space-based system is proposed. The design, based on a technique that was developed earlier by Michael, has shown excellent radiation-sensitivity performance. The mixed-mode signal circuit, using BiCMOS techniques, is currently under development. Previously fabricated VLSI ASIC chips will also be irradiated using the NPS LINAC for performance testing under a radiation environment. Past experimental results using this technique have shown great improvements in the circuit's radiation performance. Research in incorporating these designs using SOI fabrication techniques will be also considered.

CONFERENCE PUBLICATION:

Michael, S. and Presby, A., "A Novel Modeling Technique for the Design and Optimization of Advanced Thermophotovoltaic Devices for Space Nuclear and RTG Applications," *Proceedings of the 2009 Conference on Nuclear and Emerging Technologies for Space*, Atlanta, Georgia, 14-18 June 2009.

THESIS DIRECTED:

Tracey, S., "Modeling of Gallium Nitride, High-Electron Mobility Transistors on a Poly-Diamond Substrate" Master's Thesis, Naval Postgraduate School, December 2009 (second reader).

KEYWORDS: Space Radiation Effects, Satellites, Annealing, Radiation Hardened, Computer Modeling

IN SEARCH OF 40%-EFFICIENT, SPACE-BASED MULTI-JUNCTION SOLAR CELLS

Sherif N. Michael, Professor

Department of Electrical and Computer Engineering

Space Systems Academic Group

Sponsor: National Reconnaissance Office AS&T

OBJECTIVE: To explore optimization techniques to improve the efficiencies of the developed advanced, multi-junction solar cells, modeled using Silvaco software. Radiation effects on advanced cells are also modeled and investigated. The goal is to develop a design that is capable of delivering a 40%-efficient solar cell.

SUMMARY: The evaluation and optimization of a novel, multi-junction, InGaP/GaAs/Ge solar cell that was successfully modeled and fully simulated using Silvaco software. The simulation results were comparable to published experimental data of similar cells. The flexibility of the proposed methodology was demonstrated, and example results throughout the whole process were presented. Further research for the development of a more accurate model that can be used for the design and optimization of advanced, multi-junction cells was conducted. Another major goal of this research was to bridge the gap between current, state-of-the-art, manufactured cells at 30% efficiency and the theoretical limit of more than 40%.

CONFERENCE PUBLICATIONS:

Michael, S., "The Development of High Efficiency Advanced Multi-Junction Solar Cells," *Proceedings of the 2009 International Solar World Congress*, Johannesburg, South Africa, 11-14 October 2009.

Michael, S., "A Novel Design Approach of a High Efficiency Advanced Multi-Junction Cell for Solar Concentrator Applications," *Proceedings of the 2009 International Photovoltaic Science and Engineering Conference*, Jeju, Korea, 9-13 November 2009.

Tsutagawa, M. and Michael, S., "Triple Junction InGaP/GaAs/Ge Solar Cell Optimization: The Design Parameters for a 36.2% Efficient Space Cell using Silvaco ATLAS Modeling and Simulation," *Proceedings of the 34th IEEE Photovoltaic Specialists Conference*, Philadelphia, Pennsylvania, 7-12 June 2009.

THESIS DIRECTED:

Hurd, W., "Application of Copper Indium Gallium Diselenide Photovoltaic Cells to Extend the Endurance and Capabilities of Unmanned Aerial Vehicles," Master's Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: Space Radiation Effects, Satellites, Simulation, Spacecraft Power

ELECTRICAL AND COMPUTER ENGINEERING

EDDY CURRENT AND AC MODELING

Michael A. Morgan, Distinguished Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: Support in AC modeling, computation, and experimental validation related to eddy currents will be provided by the principle investigator during the summer quarter FY08 and the fall quarter FY09.

IMPULSE ANTENNA PERFORMANCE

Michael A. Morgan, Distinguished Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Dahlgren Division

SUMMARY: The performance of various Marx-driven impulse antennas elevated over lossy ground was computed using the Numerical Electromagnetics Code and Fast Fourier Transform techniques. Cases included single and arrayed dipole radiators with and without an overhead reflector.

A proposed reflector placed above a large dipole driven by a full-sized Marx was shown to provide no improvement in fields. The same reflector placed above an array of four small dipoles, each powered by a quarter-sized mini-Marx, produced an almost 50%-larger peak field in the target region below than did the large dipole with or without the reflector.

The effect of timing jitter on the four-element array was analyzed using a Monte-Carlo simulation. Field expectations were computed versus standard deviation of the random jitter in each of the array elements.

TECHNICAL REPORTS:

Morgan, M.A., "Dipole Antenna Over Lossy Ground - Progress Report No. 1," Technical Report, Naval Surface Warfare Center, Dahlgren, 16 pp., 7 November 2009.

Morgan, M.A., "Dipole Antenna Over Lossy Ground - Progress Report No. 2," Technical Report, Naval Surface Warfare Center, Dahlgren, 13 pp., 1 December 2009.

Morgan, M.A., "Impulse Antenna Performance - Final Report," Technical Report, Naval Surface Warfare Center, Dahlgren, 30 pp., 31 December 2009.

KEYWORDS: Impulse Antennas, Marx Source, Near-Fields

AN INVERSE AC PROPAGATION MODEL

Michael A. Morgan, Distinguished Professor

Department of Electrical and Computer Engineering

Sponsor: Office of Naval Research

OBJECTIVE: To develop and validate advanced computer algorithms for identifying onboard sources of AC electric and magnetic ship signatures using measured sensor data having nominal frequency content up to 3000 Hz.

SUMMARY: During this second year of a three-year funded effort, the formulation and initial testing of near-field low-frequency imaging was conducted using backpropagation of spheroidal harmonic expansions. Procedures for using noisy data measured on either spheroidal or planar surfaces were considered for estimating the spatial field distribution on a minimal size enclosing spheroidal surface. An optimal procedure based on regularized, singular-value decomposition was developed for inverting the ill-posed system of equations involved with backpropagating planar array data. Preliminary results indicated the potential for viable mapping of field sources in Naval vessels based on real-world measurements from magnetic sensor arrays. The principal investigator (PI) participated in a full-scale, experimental effort at the

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Navy's South Florida Test Range to acquire submerged magnetic and electric sensors measuring signatures for the Coast Guard ship *USS Bold*. This resulted in over 300 GB of 6 KHz time-sampled sensor data to first process prior to back-propagating signatures to create spatial field maps near to the ship hull.

PRESENTATIONS:

Morgan, M.A., "Layered Cylindrical Shielding," Office of Naval Research FY09 Research Progress Review Meeting, Naval Surface Warfare Center, Carderock Division, 11-12 August 2009.

Morgan, M.A., "Magnetic and Electric Field Imaging using Spheroidal Wave Functions," Office of Naval Research FY09 Research Progress Review Meeting, Naval Surface Warfare Center, Carderock Division, 11-12 August 2009.

TECHNICAL REPORTS:

Morgan, M.A., "Electromagnetic Similitude," Office of Naval Research Technical Report, 6 pp., 11 January 2009.

Morgan, M.A., "Inverse AC Propagation Model," Office of Naval Research FY09 Final Report, October 2009.

Morgan, M.A., "Layered Cylindrical Shielding," Office of Naval Research Technical Report, 26 pp., 11 August 2009.

Morgan, M.A., "Magnetic and Electric Field Imaging using Spheroidal Wave Functions," Office of Naval Research Technical Report, 33 pp., 11 August 2009.

KEYWORDS: Low-Frequency Electromagnetic Shielding, Magnetic Signatures

WIDEBAND ANTENNA MODELING

Michael A. Morgan, Distinguished Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Dahlgren Division

OBJECTIVE: To support the Guillotine Project in the Directed Energy Technology Office by performing numerical modeling of various wideband antenna structures, and to optimize the design of antennas using genetic algorithms.

SEMI-AUTONOMOUS CONTROL OF A MORPHING MICRO AIR-LAND VEHICLE

Capt. Corry P. Murphy, USMC, NPS Student

Department of Electrical and Computer Engineering

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: This research is a continuation of the development of a control system for the morphing micro air-land vehicle (MMALV) and the application of the Kestrel Autopilot System to the MMALV. The primary purpose of the control system is to stabilize this aircraft for use by an average person, as well as allow remote operation by an off-site user in a variety of environments and roles. The intent is to expand the capabilities of this autopilot system into a quasi primary onboard computer integrating the "whegs," a ground crawl system that is a cross between a wheel and a leg, as well as its communications capabilities, allowing for tactical networking and relay of onboard data acquisition devices (cameras, microphones, etc.) This subject was previously researched by Captain Robert Bledsoe, U.S. Marine Corps. The primary considerations with the application of both the control system and the autopilot include the size and/or weight of the overall system and the relative simplicity of use and operation. The main appeal to the U.S. military service is its vast capabilities in a small and low-cost package.

ELECTRICAL AND COMPUTER ENGINEERING

PULSED POWER SUPPLY DESIGN AND ANALYSIS FOR THE RAILGUN

Giovanna Oriti, Research Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To investigate several issues related to the power supply, including battery charging, failure modes and effects analysis, and module electrical-stress characterization.

SUMMARY: A simplified model of the electromechanical behavior of a railgun was developed in order to predict the electrical stress on a solid-state switching-power supply. A capacitor-discharge power-supply design was designed and the behavior was predicted using simulations. Of particular interest was predicting the voltage and current stress on the solid-state devices in the power supply and the snubber components selected to protect the solid-state devices. A battery charging system was designed, built, and tested. Failure mode effect and criticality analysis of the pulsed power supply was done.

PUBLICATION:

FMECA Report.

KEYWORDS: Railgun, Thyristor, Pulsed Power, Battery Charger, FMECA

CUEING RECEIVER FOR FASTER EA – RESPONSE MANAGEMENT

Phillip E. Pace, Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To continue and construct a new photonic sigma-delta (high-resolution) modulator that can sample wideband Rf waveforms directly at the antenna (digital antenna) without the need for down conversion. This research will involve the design and test of an integrated, photonic, dual-coupler, Total Internal Reflection Mirror Ring Resonator (TIRMR2) in InP/InGaAsP to replace the bulk-optic fiber lattice filter that currently exists within the Naval Postgraduate School photonic first-order sigma-delta digital antenna.

CUEING RECEIVER FOR FASTER EA RESPONSE

Phillip E. Pace, Professor
Department of Electrical and Computer Engineering
Center for Joint Services Electronic Warfare
Sponsor: Office of Naval Research

OBJECTIVE: This is a continuing effort to investigate new receiver architectures, including photonic sigma-delta modulators for digitizing the signal directly at the antenna using oversampling.

SUMMARY: A photonic, sigma-delta modulator that utilizes a mode-locked laser, wideband amplitude modulators, detectors, and high-speed comparator processors is being constructed. Also being integrated is a ring resonator (being built by UCSB) to serve as the accumulator that will be embedded in a feedback loop around the comparator processor.

CONFERENCE PUBLICATIONS:

Pace, P.E., "Cueing Receiver for Faster EA Response Management," *AOC LPI/ELINT Classified Conference*, Monterey, California, November 2009.

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Pace, P.E., Kusmanoff, A., and Fudge, G.L., "Nyquist Folding Analog-to-Information Receiver: Autonomous Information Recovery using Quadrature Mirror Filtering, *ASILOMAR Conference on Signals Systems and Computers*, November 2009.

KEYWORDS: Receiver Design, Photonics, Mode-Locked Laser, Sigma Delta Modulator, Ring Resonators

DETECTION AND CLASSIFICATION OF LOW PROBABILITY-OF-INTERCEPT RADAR

Phillip E. Pace, Professor

Department of Electrical and Computer Engineering

Center for Joint Services Electronic Warfare

Sponsor: Office of Naval Research

OBJECTIVE: This is a continuing effort to autonomously classify low probability-of-intercept (LPI) modulation types using time-frequency and bi-frequency detection techniques. Another objective is to autonomously extract the parameters of the modulation. The significance of this research is that a faster response management can be developed to counter the LPI threat emitter.

SUMMARY: During FY09, a new Choi-Williams distribution calculation was developed that significantly decreases the amount of time it takes to generate a threat signal's time-frequency response. A new cyclostationary algorithm was also developed that improves the speed of generating the bi-frequency domain for an intercepted signal.

Implementation on an SRC reconfigurable computer was explored to further increase the speed of the classification process.

CONFERENCE PUBLICATION:

Simon, W., Fouts, D., and Pace, P.E., "Cyclostationary Processing for Fast Detection of LPI Radar Signals," *AOC LPI/ELINT Conference*, November 2009.

THESES DIRECTED:

Hollinger, K., "Code Optimization for the Choi-Williams Distribution for ELINT Applications," Master's Thesis, Naval Postgraduate School, December 2009.

Simon, W., "Optimization of a Cyclostationary Signal Processing Algorithm using Multiple Field-Programmable Gate Arrays on the SRC-6 Reconfigurable Computer," Master's Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: Autonomous Classification, Low Probability of Intercept Emitters, Parameter Extraction, SRC-6

NAVAL INFORMATION OPERATIONS COMMAND-SUITLAND FY08 RESEARCH AND DEVELOPMENT

Phillip E. Pace, Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Information Operations Command-Suitland

SUMMARY: This research reflects the decision by the Naval Information Operations Command Suitland (NIOC-S) and institutes the Center for Joint Services Electronic Warfare as a focal point for all Naval Postgraduate School research proposals funded by NIOC-S. Proposals will be collected and reviewed. All proposals will be forwarded to NIOC-S for funding action. Deliverables to be provided include a quarterly budget status report to NIOC-S for each funded project. In addition, visits to NIOC-S will be coordinated and facilitated.

ELECTRICAL AND COMPUTER ENGINEERING

THE NAVY SURFACE ANTI-SHIP CAPABLE MISSILE THREAT SIMULATOR VALIDATION WORKING GROUP

Phillip E. Pace, Professor
Department of Electrical and Computer Engineering
Center for Joint Services Electronic Warfare
Sponsor: Naval Research Laboratory

OBJECTIVE: To provide technical leadership (as Chairman) to the OPNAV N433 Surface Anti-Ship Capable Missile Threat Simulator Validation Working Group (SVWG). Three types of simulations are currently being chartered for validation by the SVWG for use in test and evaluation. These include a) radio-frequency missile-hardware simulators, b) infrared missile-hardware simulators, and c) computer models of missile seekers and related electronics.

SUMMARY: The duties for the SVWG Chairman include coordinating with the Navy's Simulator Validation Coordinator, the NRL ENEWS Program Manager, and other Navy commands (e.g., Commander Operational Test and Evaluation Force) to prioritize the simulator validations for N433 approval. Additional responsibilities include coordinating with the Office of Naval Intelligence for threat data review and convening the SVWG as an independent and unbiased reviewer for all of the validation reports. A SIPRNET website is also maintained to provide a central location for all reports, plans, and threat briefs.

KEYWORDS: Anti-Ship Capable Missiles, Simulators, Captive-Carry, Hardware-in-the-Loop

ROBUST SYMMETRIC NUMBER SYSTEM VIRTUAL DIRECTION-FINDING ANTENNAS

Phillip E. Pace, Professor
David C. Jenn, Professor
Department of Electrical and Computer Engineering
Center for Joint Services Electronic Warfare
Sponsor: Navy Information Operations Command-Suitland

SUMMARY: The Naval Postgraduate School (NPS) has developed a digital phased array for direction finding that uses robust symmetric number system (RSNS) mapping to uniquely determine the angle-of-arrival of a signal. A prototype array was built using commercial, off-the-shelf hardware at 2.4 GHz. The work this year tested the array and documented the performance. In addition, a photonic RSNS digital antenna for direct digitization was developed.

Work focused on improving the antenna hardware and developing more direction finding algorithms. The investigation into the virtual processing concept was further explored and a novel architecture was derived in which only a single wideband interferometer is used to derive the phase difference of the incoming signal. The term virtual is used in the sense that the spacings for the RSNS processing are not real spacings, but virtual (imaginary) ones. The improvements will result in a system with longer operating range, variable resolution, wider bandwidth, and provide a compact package that can be field tested. Also, a photonic RSNS digital antenna that uses three interferometers to directly digitize an antenna signal was developed and tested. The photonic front end and digital signal processing were verified through performance parameters, such as the effective number of bits, the spurious free dynamic range, and the total harmonic distortion.

THESIS DIRECTED:

Arvizo, M., "Electro-Optic Analog-to-Digital Converter Architecture Based on the Robust Symmetrical Number System," Master's Thesis, Naval Postgraduate School, September 2009.

Benveniste, J., "Design and Development of a Single Channel RSNS Direction Finder," Master's Thesis, Naval Postgraduate School, March 2009.

KEYWORDS: Receiver Design, Photonics, RSNS, Direction Finding

ELECTRICAL AND COMPUTER ENGINEERING

A ROBUST SYMMETRIC NUMBER SYSTEM VIRTUAL DIRECTION-FINDING ARRAY

Phillip E. Pace, Professor

David C. Jenn, Professor

Department of Electrical and Computer Engineering

Sponsor: Navy Information Operations Command

OBJECTIVE: The Naval Postgraduate School (NPS) has demonstrated the basic operation of a digital phased array for direction finding that uses a robust symmetric number system (RSNS) mapping to uniquely determine the angle-of-arrival of a signal. A prototype array was built using commercial, off-the-shelf hardware at 2.4 GHz. The array operation was verified in the NPS anechoic chamber.

SUMMARY: Recent work focused on improving the antenna hardware and developing more DF processing functions. One technique, in particular, is a means to increase the resolution of the array by modifying the processing done on the incident plane wave samples. During the path of this investigation into the virtual processing concept, a novel architecture was derived in which only a single wideband interferometer is used to derive the phase difference of the incoming signal. The term virtual is used in the sense that the spacings for the RSNS processing are not real spacings, but virtual (imaginary) ones. The improvements will result in a system with longer operating range, variable resolution, wider bandwidth, and provide a compact package that can be field tested.

THESIS DIRECTED:

Benveniste, J., "Design and Development of a Single Channel RSNS Direction Finder," Master's Thesis, Naval Postgraduate School, March 2009.

SIGNAL DETECTION

Phillip E. Pace, Professor

Department of Electrical and Computer Engineering

Center for Joint Services Electronic Warfare

Sponsor: Naval Research Laboratory

OBJECTIVE: To extract signals of interest from flight data gathered at PAX River.

SUMMARY: Algorithms were developed to extract signal parameters from flight data. Algorithms used included a short-time Fourier transform and a quadrature mirror filter bank. GPS data was also extracted and used to quantify the detection characteristics.

THESIS DIRECTED:

Cronin, P., "Detection of Unknown Signals (U)," Master's Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Signal Detection, Classification, GPS

UAV EFFORT (CLASSIFIED RESEARCH)

Phillip E. Pace, Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Information Operations Command-Suitland

SUMMARY: UAV effort (classified research).

ELECTRICAL AND COMPUTER ENGINEERING

ULTRA-WIDEBAND ANTENNA ANALYSIS

Andrew A. Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To develop and evaluate an omni-directional antenna system to meet the sponsor's performance and mechanical/volume requirements, including uniform gain and minimal volume/weight.

ULTRA-WIDEBAND ANTENNA ANALYSIS

Andrew A. Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To model, simulate, procure, and test ultrawideband antennas in support of the Radio Reconnaissance Equipment Program (RREP).

SUMMARY: ONR/USMC RREP provides for the ultrawideband intercept of adversary communications on the battlefield in hostile zones, such as Iraq and Afghanistan. Frequency demands, size, weight, and aspect constraints necessitate extensive modeling, simulation analysis, and field tests to meet program requirements.

GED/OMA/IDG CRYPTOLOGIC RESEARCH LAB AND THESIS RESEARCH SUPPORT

R. Clark Robertson, Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

SUMMARY: Provided support for the Cryptologic Research Laboratory at the Naval Postgraduate School, wherein graduate students and faculty perform research in support of the National Security Agency's Ground Enterprise Division, Office of Mission Application, Innovations, and Discovery Group.

AN INVESTIGATION OF EMERGING COMMUNICATIONS TECHNOLOGIES

R. Clark Robertson, Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

OBJECTIVE: To investigate detection and signal processing techniques for newly emerging waveforms, such as the wavelet modem. Additionally, appropriate laboratory test equipment was acquired in order to digitize and analyze these newly emerging signals.

SUMMARY: Conventional modems often adopt orthogonal frequency-division multiplexing (OFDM) standards such as IEEE 802.11g, IEEE 802.11n, and IEEE 802.16e. A newly developed waveform utilizes wavelet-division multiplexing instead of OFDM. This new technology requires study to determine detection techniques and optimal waveform signal processing. A broadband signal analyzer and recorder was acquired and will be used to digitize and analyze the wavelet modem waveform. The results of the analysis will be used to develop new techniques to detect and optimally process this new waveform. It has been asserted that the wavelet modem generates a featureless waveform; however, it was determined that the waveform is not featureless, and these features can be used to exploit the waveform. This work is ongoing.

KEYWORDS: Spread Spectrum, Frequency-Hopping, Featureless Waveforms

ELECTRICAL AND COMPUTER ENGINEERING

NATIONAL SECURITY AGENCY/APPLIED TECHNOLOGY DIVISION CRYPTOLOGIC RESEARCH LAB AND THESIS RESEARCH SUPPORT

R. Clark Robertson, Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

SUMMARY: Provided support for the Cryptologic Research Laboratory at the Naval Postgraduate School, wherein graduate students and faculty perform research in support of the National Security Agency's Applied Technology Division.

NSA/I&DG CRYPTOLOGIC RESEARCH LAB AND THESIS RESEARCH SUPPORT

R. Clark Robertson, Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

OBJECTIVE: To support the continued expansion of the National Security Agency (NSA)-sponsored Cryptologic Research Laboratory (CRL) and the conduct of research therein, which will encompass major cryptologic/information operations areas as tasked by the sponsoring agency.

SUMMARY: The National Security Agency's Innovations and Discovery Group (I&DG) has provided both monetary and equipment resources over the past several years to establish the Cryptologic Research Laboratory at the Naval Postgraduate School (NPS). The CRL is operational and the I&DG's goals for this laboratory are twofold: to produce advanced SIGINT solutions using highly trained, technically skilled, NPS personnel at a relatively low investment; and to produce military officers with relevant SIGINT experience that can make an impact on the cryptologic community. The CRL operates in direct support of the NPS mission by providing the tools to facilitate the higher education of military officers and produce the knowledge, technology, and techniques needed by U.S. and allied forces to enhance national security.

This is accomplished by performing three major functions:

- Producing military officers that are technically educated and experienced in cryptologic/IO related issues.
- Conducting advanced technical research at the graduate and postgraduate levels that supports sponsor requirements.
- Producing written theses and technical reports and developing advanced cryptologic/IO hardware, software, and techniques for operational use.

On a periodic basis, NSA/I&DG submits CRL research topics, in the form of a request for proposal (RFP) or tasking statement, to the CRL Lab Director by electronic means (NSANet or unclassified email). The CRL Lab Director reviews these RFP's (tasking statements) with other faculty members to solicit inputs.

KEYWORDS: COMINT, Detection, Recognition, Exploitation, Sensors, Communications

SEPARATION OF FREQUENCY-HOPPING NETWORKS USING INDEPENDENT COMPONENT ANALYSIS

R. Clark Robertson, Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

OBJECTIVE: To investigate the efficacy of using independent component analysis to separate multiple frequency-hopping networks from one another.

ELECTRICAL AND COMPUTER ENGINEERING

ENGINEERING SMALL SATELLITES FOR SPACE-BASED EQUIPMENT

Alan A. Ross, Professor

Department of Electrical and Computer Engineering

Sponsor: Secretary of the Air Force/FMBIB

OBJECTIVE: To further investigate the previous year's small satellite designs and prepare for future year prototypes.

SURFACE WARFARE DEVELOPMENTS – RESEARCH AND LAB SUPPORT

Weilian Su, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Sea Systems Command

OBJECTIVE: To investigate new network extraction techniques.

SUMMARY: Research conducted under this project included analysis of web and network vulnerability data.

KEYWORDS: Internet, World Wide Web, Hacking Resources, Network Intrusion

SLAM ROBOTICS

LT Antonio Valle, USN, NPS Student

Department of Electrical and Computer Engineering

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To develop an autonomous robot with the capability to perform localization and mapping functions simultaneously. A sensor suite will be constructed to fulfill the previously mentioned capabilities; the suite will include range sensors and a gyroscope. A central control board will be programmed with an algorithm that will allow the robot to navigate a room, map the room, and localize the robot's position. Furthermore, the algorithm will be implemented and tested in a static or semi-static lab environment.

GALLIUM NITRIDE HEMT RELIABILITY

Todd Weatherford, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Air Force Research Laboratory, Wright Patterson Air Force Base

OBJECTIVE: To assist the Sensors Directorate in understanding investigating reliability of compound semiconductor technologies. To support GaN on the Diamond Program with SP3 and AFRL. To support a review of AFOSR and ONR MURIs on component reliability.

SUMMARY: Work in 2009 included modeling GaN HEMT reliability and monitoring MURI programs.

CONFERENCE PUBLICATIONS:

Weatherford, T., Wang, Y., and Tracey, S., "Self Heating of AlGaIn/GaN HEMTs in Pulsed Operation," *JEDEC/IEEE Workshop on Reliability of Compound Semiconductors Proceedings*, pg. 59-69, Greensboro, North Carolina, October 2009.

Weatherford, T., Wang, Y., and Tracey, S., "TCAD Analysis of Self Heating in AlGaIn/GaN HEMTs under Pulsed Conditions," *IEEE International Integrated Reliability Workshop*, pg. 159-162, South Lake Tahoe, California, October 2009.

ELECTRICAL AND COMPUTER ENGINEERING

PRESENTATIONS:

Tracey, S., Weatherford, T., and Wang, Y., "Transient TCAD Modeling of Electro-Thermal Self Heating in GaN HEMTS," Microelectronics Reliability and Qualification Workshop, Manhattan Beach, California, December 2009.

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Weatherford, T., Wang, Y., and Tracey, S., "TCAD Analysis of Self Heating in AlGaIn/GaN HEMTs under Pulsed Conditions," IEEE International Integrated Reliability Workshop, South Lake Tahoe, California, October 2009.

THESIS DIRECTED:

Tracey, Y., "Prediction of GaN HEMTs IV Characteristics over Temperature and Thermal Profiling," Master's Thesis, Naval Postgraduate School.

GALLIUM NITRIDE HEMT RELIABILITY STUDIES

Todd Weatherford, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Air Force Research Laboratory

OBJECTIVE: To investigate end-of-life (EOL) reliability of gallium nitride (GaN)-based high-electron mobility transistors (HEMTs) for the Air Force Research Laboratory (AFRL) Space Program. The GaN HEMT provides extended bandwidth, efficiency, power density, higher thermal operation, and reduced circuit complexity over other semiconductors. Only EOL reliability has limited GaN technology's transition to Department of Defense systems. Deliverables will be electronically transmitted and will include theses, reports, and other publications.

GTO THYRISTOR RELIABILITY INVESTIGATIONS

Todd Weatherford, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Office of Naval Research

OBJECTIVE: To investigate the failure of IGBTs in specific railgun switching circuits.

SUMMARY: Work in 2009 included developing simulations to understand electrical and thermal properties of IGBTs in power circuits.

CONFERENCE PUBLICATION:

Ciezki, J., Vineyard, G., and Weatherford, T., "The Investigation of the Electro-Thermal Characteristics of a GTO Thyristor at Turn-Off using Silvaco ATLAS," *IEEE International Integrated Reliability Workshop Final Report*, South Lake Tahoe, California, pg. 151-154, October 2009.

PRESENTATIONS:

Ciezki, J., Vineyard, G., and Weatherford, T., "The Investigation of the Electro-Thermal Characteristics of a GTO Thyristor at Turn-Off using Silvaco ATLAS," IEEE International Integrated Reliability Workshop, South Lake Tahoe, California, October 2009.

ELECTRICAL AND COMPUTER ENGINEERING

Weatherford, T., Vineyard, G., and Ciezki, J., "Joule Heating TCAD Analysis of Gate-Turn-Off (GTO) Thyristors," Microelectronics Reliability and Quality Workshop, Manhattan Beach, California, December 2009.

THESIS DIRECTED:

Vineyard, G., "Investigating the Electrothermal Characteristics of a Gate Turn Off Thyristor during Turn-Off using Silvaco Atlas," Master's Thesis, Naval Postgraduate School, June 2009.

LINAC/FLASH XX-RAY RADIATION TESTING OPERATIONS

Todd Weatherford, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Various

OBJECTIVE: To provide beam time and tech support at the Flash X-Ray facility.

SUPPORT FOR THE NAVAL POSTGRADUATE SCHOOL FLASH X-RAY

Todd Weatherford, Associate Professor

Andrew A. Parker, Research Associate

Department of Electrical and Computer Engineering

Sponsor: Various

OBJECTIVE: To operate the Flash X-Ray facility in support of instruction and Department of Defense research initiatives.

SUMMARY: In 2009, the Center for Radiation Hardened Electronics has supported internal NPS research related to rad-hard electronics for space and strategic systems. The Center also supported Naval Postgraduate School classes related to microelectronics reliability for space systems. Outside researchers from SAIC/Suntronics and SpaceMicro used the facilities for radiation effects research in 2009, supporting GPS, Advanced EHF, SBIRs, Minuteman, and other systems.

SUPPORT FOR THE NAVAL POSTGRADUATE SCHOOL LINEAR ACCELERATOR

Todd Weatherford, Associate Professor

Andrew A. Parker, Research Associate

Department of Electrical and Computer Engineering

Sponsor: Various

OBJECTIVE: To operate the Naval Postgraduate School (NPS) Linear Accelerator (LINAC) and Flash X-ray facilities.

SUMMARY: In 2009, the Center for Radiation Hardened Electronics supported internal NPS research related to rad-hard electronics for space and strategic systems. The Center also supported NPS classes related to reliability and space systems. Outside researchers from SAIC and Suntronics used the facilities for radiation effects research in 2009, supporting GPS, Advanced EHF, SBIRs, Minuteman, and other systems.

ELECTRICAL AND COMPUTER ENGINEERING

USE OF THE NPS FLASH X-RAY FACILITY

Todd Weatherford, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Science Applications International Corps

OBJECTIVE: The Naval Postgraduate School will provide beam time and technical support at the Flash X-Ray facility. Sessions will be scheduled and funded as required.

REDUCED CREW SIZE METROLOGY USING WIRELESS LANS

Xiaoping Yun, Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Corona

OBJECTIVE: To study the feasibility of developing a web-based temperature-sensor calibration system.

SUMMARY: The project effort was focused on building a suitable temperature bath-transducer system for real-time data acquisition and on establishing models and time constants for various RTD and thermocouples. A precision calibration bath (model 7320) from Hart Scientific was acquired and interfaced to a web server with the aid of Labview programs. A number of RTD and thermocouples were also interfaced to the web server using NI real-time PowerPC Controllers and Labview programs. The feasibility of the developing a web-based calibration system was preliminarily established.

KEYWORDS: Metrology, Wireless LAN, Calibration, Temperature Sensors

REDUCED CREW SIZE METROLOGY USING WIRELESS LANS AND WEARABLE PCS

Xiaoping Yun, Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center-Corona Division

OBJECTIVE: To specifically assist MSD to improve and field the pressure calibration system; to initiate the design and prototyping of other calibration systems, including that for temperature gages; and to generally assist MSD in identifying common areas for the Naval Postgraduate School and MSD to further collaborate and initiate studies and activities to further the objectives of both activities.

**DEPARTMENT OF
ELECTRICAL AND
COMPUTER ENGINEERING**

**2009
Faculty Publications
and Presentations**

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ELECTRICAL AND COMPUTER ENGINEERING

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**DEPARTMENT OF
MECHANICAL AND
AEROSPACE ENGINEERING**

**KNOX T. MILLSAPS
CHAIRMAN**

MECHANICAL AND AEROSPACE ENGINEERING

OVERVIEW:

The Department of Mechanical and Aerospace Engineering (MAE) provides a strong academic program that spans the engineering disciplines of thermal-fluid sciences, structural mechanics, dynamic systems, guidance and control, materials science and engineering, propulsion, and systems engineering, including total ship systems engineering, spacecraft, and missile design. These disciplines are blended together with a strong emphasis on naval engineering applications required by surface vessels, submarines, and spacecraft. Furthermore, the department provides advanced education in classified topics in astronautical engineering. Programs leading to the degree of Master of Science in Mechanical Engineering or Master of Science in Astronautical Engineering are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET). A specific curriculum must be consistent with the general minimum requirements for the degree as determined by the academic council. Any program leading to a degree must be approved by the department chair at least two quarters before completion. In general, approved programs will require more than the stated minimum degree requirements in order to conform to the needs and objectives of the United States Navy and satisfy the applicable subspecialty-code requirements.

RESEARCH MISSION:

To increase the combat effectiveness of U.S. and allied armed forces and to enhance the security of the United States through research in areas related to mechanical engineering, spanning the field from basic phenomena to engineering design, development, operation, maintenance, and disposal of components and systems for naval platforms.

CURRICULA SERVED:

The MAE Department serves the Naval and Mechanical Engineering curriculum (570), the Mechanical and Reactors-Engineering curriculum (571), the Mechanical Engineering program for deployed nuclear-trained officers curriculum (572), and the Space-Systems Engineering curriculum (591). These curricula support the Navy's need for individuals with advanced technical education in mechanical and astronautical engineering and related fields. The 570 curriculum provides the educational component for the engineering duty-officer program, and the research program in the department is designed to support the requirement for officers to have the ability to identify, formulate, and solve technical and engineering problems in areas related to mechanical engineering. The Space-Systems Engineering program provides officers with a comprehensive, scientific, and technical knowledge of national security, military, and naval space-systems.

DEGREES GRANTED:

- Master of Science in Mechanical Engineering
- Master of Science in Astronautical Engineering
- Master of Science in Engineering Science (Mechanical Engineering)
- Master of Science in Engineering Science (Astronautical Engineering)
- Mechanical Engineer
- Astronautical Engineer
- Doctor of Philosophy in Mechanical Engineering
- Doctor of Philosophy in Astronautical Engineering

MECHANICAL AND AEROSPACE ENGINEERING

RESEARCH THRUSTS:

- Fluid Dynamics, Heat Transfer, and Turbomachinery
- Combustion, Energy Systems, Alternate and Synthetic Fuels
- Pulse Detonation Engines, Rotordynamics, Fluid-Structure Interactions
- Dynamic Systems, Controls, and Robotics
- Autonomous Systems, Unmanned Systems, Guidance and Control, and Space Robotics
- Solid Mechanics, Vibrations, Structures
- Computational Mechanics, and Ship Shock, Design, and Optimization
- Materials Science and Engineering
- Friction Stir Processing and Welding
- Space-Systems, Adaptive Optics, Astrodynamics Optimization
- Total Ship Systems Engineering

FACULTY EXPERTISE:

- **Fluid Dynamics, Heat Transfer, and Turbomachinery:**
Professor Knox Millsaps, Associate Professor Chris Brophy, Professor Garth Hobson
- **Dynamic Systems, Controls, and Robotics:**
Distinguished Professor Brij Agrawal, Professor Morris Driels, Professor Isaac Kaminer, Associate Professor Fotis Papoulas, Assistant Professor Marcello Romano, Professor I. Michael Ross, Professor Oleg Yakimenko
- **Solid Mechanics, Vibration, and Shock:**
Professor Young W. Kwon, Associate Professor Joshua Gordis
- **Materials Science and Engineering:**
Professor Terry McNelley, Professor Indranath Dutta
- **Space-Systems:**
Distinguished Professor Brij Agrawal, Professor Isaac Kaminer, Assistant Professor Marcello Romano, Professor I. Michael Ross
- **Total Ship Systems Engineering:**
Associate Professor Fotis Papoulas

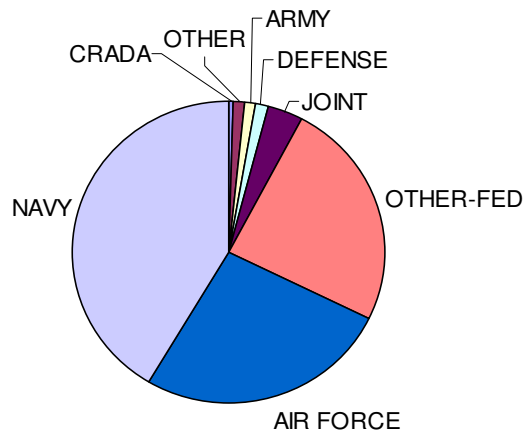
RESEARCH FACILITIES:

The mechanical engineering laboratories are designed as complements to the educational mission and research interests of the department. In addition to extensive facilities for the support of student and faculty research, a variety of general use equipment is available. This includes equipment and facilities for the investigation of problems in engineering mechanics; a completely equipped materials science laboratory, including advanced scanning electron microscopes, an Auger microprobe, a transmission electron microscope, and X-ray diffractometers; an oscillating water tunnel, a unique underwater towing tank and a low-turbulence water channel; a vibration analysis laboratory; a fluid power controls laboratory; a robotics and real-time control laboratory; facilities for experimentation with low-velocity air flows; equipment for instruction in thermal transport phenomena; a laser Doppler velocimeter; nuclear-radiation detection equipment; and an interactive CAD/CAE computer-graphics laboratory. Experimentation is further enhanced by a broad selection of analog and digital data acquisition and processing equipment and instrumentation.

MECHANICAL AND AEROSPACE ENGINEERING

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Mechanical and Aerospace Engineering is provided below:



Size of Program: \$7.8

MECHANICAL AND AEROSPACE ENGINEERING

Knox T. Millsaps
Professor and Chairman
DoD Executive Agent for SMART Scholarship-for-Service Program
831-656-3382
millsaps@nps.edu

Garth V. Hobson
Professor and Associate Chairman
831-656-2888
gvhobson@nps.edu

Christopher A. Adams
Lecturer
831-656-3400
caadams@nps.edu

Muguru Chandrasekhara
Research Professor
831-656-3585
mchandra@nps.edu

Shesh Hebbar
Senior Lecturer
831-656-1103
shebbar@nps.edu

Brij N. Agrawal
Distinguished Professor
831-656-3338
agrawal@nps.edu

Jarema M. Didoszak
Research Associate Professor
831-656-2604
jmdidosz@nps.edu

Douglas Horner
Research Assistant Professor
831-656-3821
dphorner@nps.edu

Terry Alfried
Visiting Professor
831-656-3929
ktalfrie@nps.edu

Vladimir N. Dobrokhodov
Research Assistant Professor
831-656-7714
vldobr@nps.edu

Kevin D. Jones
Research Associate Professor
831-656-7711
jones@nps.edu

Robert E. Ball
Distinguished Professor
Emeritus
831-601-3819
reball@mac.com

Morris R. Driels
Professor
831-656-3383
mrdriels@nps.edu

Isaac I. Kaminer
Professor and
NPS Director of
Aerodynamic Decelerator
Systems Center
831-656-3459
kaminer@nps.edu

Oscar Biblarz
Professor Emeritus
831-656-3096
obiblarz@nps.edu

Indranath Dutta
Professor
831-656-2851
idutta@nps.edu

Matthew D. Kelleher
Professor Emeritus
831-656-2530
mkelleher@nps.edu

Luke Brewer
Associate Professor
831-656-3382
lnbrewer@nps.edu

Anthony J. Gannon
Research Assistant Professor
ajgannon@nps.edu

Jae-Jun Kim
Research Assistant Professor
831-656-2716
jki1@nps.edu

Christopher M. Brophy
Associate Professor and
Academic Associate
831-656-2327
cmbrophy@nps.edu

Joshua H. Gordis
Associate Professor and
Academic Associate
831-656-2866
gordis@nps.edu

Ramesh Kolar
Research Assistant Professor
831-656-2854
rkolar@nps.edu

Charles N. Calvano
Professor Emeritus
831-656-2334
calvano@nps.edu

Anthony J. Healey
Distinguished Professor and
Director, Center for AUV
Research
831-656-3462
healey@nps.edu

Sean P. Kragelund
Research Associate
831-656-2438
spkragel@nps.edu

MECHANICAL AND AEROSPACE ENGINEERING

Young W. Kwon
Professor
831-656-2238
ywkwon@nps.edu

John R. Lloyd
Distinguished Visiting
Professor
831-656-3400
jrlloyd@nps.edu

Tad D. Masek
Research Associate
831-656-1161
tdmasek@nps.edu

Terry R. McNelley
Distinguished Professor
831-656-2589
tmcnelley@nps.edu

Sarath K. Menon
Research Professor
831-656-2551
skmeno1@nps.edu

Fotis A. Papoulas
Associate Professor
831-656-3381
papoulas@nps.edu

Maximilian F. Platzer
Distinguished Professor
Emeritus
831-656-3426
mplatzer@nps.edu

Ty Pollak
Assistant Professor
831-656-1144
rdpollak@nps.edu

Marcello Romano
Associate Professor
831-656-2885
mromano@nps.edu

I. Michael Ross
Professor
831-656-2074
imross@nps.edu

Turgut Sarpkaya
Distinguished Professor
Emeritus
831-656-3425
sarp@nps.edu

Alan D. Scott
Senior Lecturer
831-656-2453
adscott@nps.edu

Douglas L. Seivwright
Research Associate
831-656-3718
dlseivwr@nps.edu

Young S. Shin
Distinguished Professor
831-656-2568
yshin@nps.edu

Raymond P. Shreeve
Professor Emeritus
831-656-2593
shreeve@nps.edu

E. Roberts Wood
Professor Emeritus
831-656-2897
wood@nps.edu

Oleg Yakimenko
Research Professor
831-656-2826
oayakime@nps.edu

MECHANICAL AND AEROSPACE ENGINEERING

SPACECRAFT SURVIVABILITY

Christopher A. Adams, Lecturer

Department of Mechanical and Aerospace Engineering

Sponsor: Lockheed Martin Space Systems Company

SUMMARY: Since the mid-1970s, the Naval Postgraduate School (NPS) has been the world's leading academic institution in the analysis and design of survivability of combat systems. Work in the area of aircraft survivability is the model that other platforms emulate to ensure the survivability and security of their systems. The Naval Postgraduate School's Center for Survivability and Lethality is the world's leader in multi-platform survivability. It was established as a Center of Excellence for education and research in survivability and lethality by coordinating the interdisciplinary efforts of faculty, program managers, engineers, and industry.

Lockheed Martin Space Systems and the Naval Postgraduate School will work to further develop the concept of spacecraft survivability, spacecraft-survivability engineering methodologies, and spacecraft survivability analysis.

SUPPORT FOR JOINT AIRCRAFT SURVIVABILITY AND CENTER FOR SURVIVABILITY

Christopher A. Adams, Lecturer

Department of Mechanical and Aerospace Engineering

Sponsor: Joint Aircraft Survivability Program Office

OBJECTIVE: To explore the development of a long-term relationship between the Naval Postgraduate School Center for Survivability and Lethality and the Joint Aircraft Survivability Program Office (JASPO). Activities will support the goals and mission of JASPO.

ACTIVE OPTICS CONTROL STUDIES

Brij N. Agrawal, Distinguished Professor

Department of Mechanical and Aerospace Engineering

Sponsor: National Reconnaissance Office

OBJECTIVE: Under this task agreement, the Spacecraft Research and Design Center (SRDC) of the Naval Postgraduate School (NPS) will perform the following tasks related to segmented mirror technology for the Advanced Systems and Technology/Advanced Technology Group (AS&T/ATG) of the National Reconnaissance Office (NRO). Priority and a detailed scope of the tasks shall be agreed between AS&T/ATG and SRDC on the basis of need and available resources. The tasks are to provide support to the Segmented Mirror Testbed (SMT) Program, mitigation of vibrational and acoustic perturbations, realignment of OTA, improvement of wave-front sensors for segmented mirrors, robust control of multi-output, segmented-mirror, adaptive optics, and jitter control using adaptive filters.

ADAPTIVE POINTING CONTROL FOR SPACECRAFT

Brij N. Agrawal, Distinguished Professor

Department of Mechanical and Aerospace Engineering

Sponsor: National Reconnaissance Office

OBJECTIVE: To develop and evaluate robust, adaptive-control techniques for accurate pointing and tracking of spacecraft with flexible appendages, external disturbances, and un-modeled dynamics. The main issues are the estimation of the inertia matrix and the need for compensating for vibration effects due to flexible appendages. The proposed controller must guarantee sufficient robustness and a "well behaved" response to be deployed in space in an unsupervised environment.

MECHANICAL AND AEROSPACE ENGINEERING

AN ADVANCED INERTIAL REFERENCE UNIT

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Air Force Research Laboratory

OBJECTIVE: To maintain the advanced inertial reference unit (AIRU) in an operational state at the Naval Postgraduate School (NPS) for use by the students, and to engage in efforts to improve its performance. This unit was developed by Applied Technology Associates (ATA) for the Missile Defense Agency; NPS received it in 2007. The main tasks will consist of moving the AIRU from the NPS Optical Relay Laboratory to the clean room of Adaptive Optics Beam Control Laboratory, developing a simple scoring system, performing review of previous development work on the IRU, upgrading jitter control algorithms, providing optical cage control, and replacing the collimator with a new collimator from ATA.

THE APPLICATION OF ADVANCED WAVEFRONT SENSING AND CONTROL TECHNIQUES TO A HIGH-ENERGY-LASER BEAM-CONTROL TESTBED

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: High Energy Laser Joint Technology Office

OBJECTIVE: To upgrade the Naval Postgraduate School high-energy, laser-beam control testbed by adding an atmospheric disturbance generator, a deformable mirror, and a wavefront sensor in phase one, and an aircraft and ship-vibration simulator in phase two. The scope also includes the development of advanced control techniques, such as adaptive control for acquisition, tracking, and pointing and a multi-channel transversal filter and robust control for beam correction under atmospheric disturbance, and validation of these techniques.

THE CENTER FOR ADAPTIVE OPTICS

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: This five-year project supports advanced research and graduate-level education in adaptive optics to create a center for defense-related adaptive optics. Specifically, these funds will support the development and enhance the collaborative efforts with the Center for Adaptive Optics, University of California, Santa Cruz (UCSC). The Naval Postgraduate School (NPS) has an active research program in adaptive optics under the Spacecraft Research and Design Center to support defense missions, such as imaging spacecraft, laser communications spacecraft and beam control for high-energy lasers. UCSC has an NSF-funded Center for Adaptive Optics, which places emphasis on astronomical and biomedical applications. There are several areas of common research interest in adaptive optics for NPS and the UC Santa Cruz centers. Some of the common areas currently identified are jitter control, predictive control for air turbulence, and advanced wavefront sensors. This collaborative research effort will help advance the state-of-the-art in adaptive optics with applications to defense, civilian, and commercial missions. It will also help advance graduate-level education in the field of adaptive optics.

LARGE-APERTURE, LIGHTWEIGHT, SPACE-BASED OPTICS – PHASE III

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To improve adaptive-optics control techniques for flexible, deployable, space-mirror surface and beam control and to minimize image aberrations. This is a continuing project.

MECHANICAL AND AEROSPACE ENGINEERING

MARITIME BEAM CONTROL

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To develop beam control technologies for future maritime, free-electron-laser (FEL) weapon systems, and to educate Department of Defense officers in this important area. The emphasis of this research will be on developing improved control techniques to enhance acquisition, tracking, and pointing, jitter control, and adaptive optics for turbulence correction for maritime beam control. It is planned that a high-energy laser (HEL) beam-control testbed will be developed and field tests will be performed. Phase one will consist of reviewing the requirements for maritime beam control. Phase two will consist of developing the HEL beam-control testbed. Phase three will consist of developing control algorithms to improve beam-control performance. Phase four will consist of modifying the testbed for field tests. Phase five will consist of performing field tests. This project will also support the FEL program on beam-control issues.

MARITIME BEAM CONTROL/REDUNDANT SPACINGS CALIBRATION

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To develop an improved wavefront sensor based on redundant spacings calibration (RSC) for the purpose of compensating for atmospherically induced beam-wander of an HEL system in a maritime environment; and to allow amalgamation of a wavefront-sensing and target-tracking apparatus and the elimination of a beacon laser. The RSC technique had previously been established for the calibration of piston phase errors only, affecting interferometric arrays. In this research, the proposal is to extend the analysis to allow calibration of higher order phase modes. By selectively sampling repeated (or redundant) spatial frequency components of the object light, the aberration phase component can be separated from the object information. This should eliminate the need for a reference laser, with measurements being made from the image itself, and may also permit the combination of the wavefront-sensing detector with the imaging and aim-point maintenance apparatus. Improvements are expected in the dynamic range and speed of the wavefront solution over other popular sensors. This wavefront sensing technique has many potential applications. It is currently being investigated for the phasing of segmented telescopes, but it can also apply to the calibration of phased arrays under atmospheric turbulence conditions.

ON-ORBIT SYSTEM IDENTIFICATION AND SLEW MANEUVER FOR FLEXIBLE SPACECRAFT

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To develop and evaluate techniques for on-orbit system identification and slew maneuver control of flexible spacecraft with control moment gyroscopes (CMGs). The emphasis of this research will be on minimizing residual vibrations and slew maneuver time for enhanced acquisition and pointing performance. With the current spacecraft design trends of increased flexibility, multiple modular bodies, and stringent attitude-control accuracy requirements, slew control design may need improvements to accomplish future spacecraft missions.

During FY2008, input shaping techniques were investigated for three-axis slew-maneuver problems, including the nonlinear term in the spacecraft equation of motion. This approach provides a simple way to design slew control within the available momentum space of the CMG array. Experiments using the Bifocal Relay Mirror Spacecraft (BRMS) simulator were also performed. In order to use the full momentum space of the CMG array, it is necessary to solve an optimization problem with nonlinear dynamic equations. Slew-maneuver control design using a sequential linear programming (SLP) technique was also investigated.

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In FY09, the SLP optimization technique and system identification method using a filter bank approach will be extended for three-axis, rotational, flexible spacecraft and will be implemented on the experimental testbed. The adaptive filters will be also investigated in FY09. The star tracker sensor will be integrated on the BRMS simulator for accurate determination of the spacecraft attitude.

ROBUST ADAPTIVE CONTROL WITH EXTERNAL DISTURBANCES AND UNMOLDED DYNAMICS

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To develop and evaluate robust adaptive-control techniques for accurate pointing and tracking of spacecraft with flexible appendages, external disturbances, and unmodeled dynamics. The main issues are the estimation of the inertia matrix and the need for compensating for vibration effects due to the flexible appendages. The proposed controller must guarantee sufficient robustness and a “well behaved” response to be deployed in space in an unsupervised environment.

SPACE TECHNOLOGY DEVELOPMENT

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Operationally Responsive Space Office

OBJECTIVE: To perform a preliminary design of a multi-mission spacecraft consisting of both a modular spacecraft bus and optical payloads for the Operationally Responsive Space (ORS) Office. The optical payloads to be considered are the LEO Electro-Optical Visible Near Infrared Imager, the LEO EO/Shortwave-Infrared Imager, the LEO Hyperspectral Imager (HSI), and the LEO Deep Space Object Search and Track. The orbits to be considered are sun-synchronous, mid-latitude, and equatorial. The launch vehicles to be considered are Minotaur-class, Pegasus, Taurus, and Falcon-class. It is desirable to have modular architectures based on open, non-proprietary standards and architectures, such as the AFRL plug-n-play standards.

A SPACECRAFT DESIGN

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Operationally Responsive Space Office

OBJECTIVE: To perform a preliminary design of an operationally responsive, modular spacecraft with a plug-and-play bus architecture and a synthetic-aperture-radar payload for the maritime domain awareness mission.

A SPACECRAFT SYSTEM

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To develop and operate spacecraft laboratories to provide noteworthy improvement to the Space Systems curricula. This project has resulted in the development of six state-of-the-art spacecraft laboratories at the Naval Postgraduate School (NPS). During 2008, several major achievements were made in the development of the laboratories. The new Adaptive Optics Beam Control Laboratory became operational. New research capabilities, including the HEL Beam Control testbed, the AIRU testbed, and the Wavefront Sensing testbed, were installed. For the FLTSATCOM Laboratory, a technical support contract for the TT&C upgrade was awarded. In the Spacecraft Design Laboratory, the aerospace design software

MECHANICAL AND AEROSPACE ENGINEERING

tools were upgraded on all student workstations, and several new workstations and a color laser printer were added. In the NPS-AFRL Optical Relay Mirror Laboratory, a new star tracker was acquired for the three-axis spacecraft simulator. For the Smart Structures Laboratory, a new smart-vibration beam-system testbed is under development. During 2008, under course AE 4871, NPS students provided a preliminary design of the Operationally Responsive Space (ORS) iSAT. In 2009, the TT&C system upgrade for the FLTSATCOM Laboratory will be completed. For the Spacecraft Design Laboratory, the maintenance/upgrading of the aerospace design tools and technical library will continue.

SPACECRAFT SYSTEMS STUDIES

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To conduct spacecraft studies in two areas: evaluation of three-axis stabilization versus dual-spin stabilization for communications satellites, and independent control of multiple payloads by multiple users.

TACTICAL HEL WEAPON ALIGNMENT SYSTEM ARCHITECTURE EFFICIENCIES

Brij N. Agrawal, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To perform a preliminary design of a multi-mission spacecraft consisting of both a modular spacecraft bus and optical payloads for the Operationally Responsive Space (ORS) Office. The optical payloads to be considered are the LEO Electro-Optical Visible Near Infrared Imager, the LEO EO/Shortwave-Infrared Imager, the LEO Hyperspectral Imager (HSI), and the LEO Deep Space Object Search and Track. The orbits to be considered are sun-synchronous, mid-latitude, and equatorial. The launch vehicles to be considered are Minotaur-class, Pegasus, Taurus, and Falcon-class. It is desirable to have modular architectures based on open, non-proprietary standards and architectures, such as the AFRL plug-n-play standards.

CONSTANT VOLUME COMBUSTION TECHNOLOGY DEVELOPMENT

Christopher M. Brophy, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Air Force Research Laboratory

SUMMARY: The Rocket Propulsion Laboratory will perform research in the area of constant-volume combustions in support of pulse-detonation-engine technology. Each area of research either permits the efficient and reliable generation of detonation waves or produces conditions required for practical engine operation. Since all experimental testing relies on properly simulating the expected flight conditions, the vitiated air-heating system will be replaced with a heat-exchanger approach to deliver hot/dry air to the various test articles. Some of the existing imaging diagnostics may be modified and upgraded to properly characterize flow fields of interest under both single-cycle and multi-cycle operation. Areas of research will include low-loss, swept-ramp, obstacle fields; transient plasma ignition; and a fluidic flow switching survey.

MECHANICAL AND AEROSPACE ENGINEERING

HEAT TRANSFER PROPERTIES OF LAUNCH-FLASH PLUME IMPINGEMENT

Christopher M. Brophy, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Air Force Research Laboratory

OBJECTIVE: To determine the heat transfer properties associated with plume impingement during the ignition and launch sequence of a solid-propellant rocket motor. The heat transfer will be correlated to plume composition and additional IR imaging.

PDE DEVELOPMENT AND QUALIFICATION ON THRUST VECTORING CAPABILITIES

Christopher M. Brophy, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To investigate new detonation-initiation strategies through novel swept-ramp fuel injectors/turbulence generators, and to evaluate their performance on a multi-cycle pulse-detonation engine. Additionally, a new three-combustor engine with a common exhaust nozzle will be designed and fabricated to evaluate the effectiveness of mixed frequency operation of individual tubes resulting in near-instantaneous thrust vectoring.

TESTING OF THE HYBRID ACOUSTIC IGNITER

Christopher M. Brophy, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Sierra Engineering, Inc.

OBJECTIVE: To provide a testing facility and technical expertise to test the novel acoustic igniter at the Rocket Test Laboratory. The test is expected to define the characteristics of resonant heating and demonstrate ignition.

DYNAMIC-STALL UNSTEADY-FLOW EXPERIMENTS

Muguru S. Chandrasekhara, Research Professor
Department of Mechanical and Aerospace Engineering
Sponsor: NASA Ames Research Center

OBJECTIVE: To conduct unsteady-flow measurements under dynamic-stall flow conditions and to continue supporting ongoing, experimental, flow separation control research related to helicopter rotors through acquisition and analysis of compressible flow data at the U.S. Army, Aeroflightdynamics Directorate (AFDD) located at Moffett Field, California, over the next two years. Additionally, a new effort that includes specification and design of advanced flow-measurement systems and assists in experimental studies using these systems at U.S. AFDD at Moffett Field is proposed.

MISSILE AERODYNAMICS PREDICTION STUDIES

Muguru S. Chandrasekhara, Research Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Defense Intelligence Agency

OBJECTIVE: To leverage Naval Postgraduate School (NPS) knowledge and experience to develop efficient methods for six degree-of-freedom (6-DOF) missile aerodynamic coefficient estimation using emerging scientific concepts and the latest computational tools. The specific task is to develop a method and estimation aerodynamic coefficients for a generic SA-family missile with modified nose geometry.

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STEADY AND UNSTEADY-FLOW EXPERIMENTS ON ROTOR ISSUES

Muguru S. Chandrasekhara, Research Professor
Department of Mechanical and Aerospace Engineering
Sponsor: U.S. Army Aero-Flight Dynamics Directorate

SUMMARY: To develop and conduct very basic unsteady-flow studies, first on simplified geometries, with the goal of expanding the knowledge-base in order to obtain a better understanding of helicopter rotor-blade complex-flow issues, including compressible dynamic stall and its control.

To lend the principal investigator's expertise to ongoing current and proposed rotor-flow-control-related experiments through developing new instrumentation and data acquisition techniques and applying them to document research activities.

UNSTEADY AERODYNAMICS RESEARCH OF A MANEUVERING UCAV

Muguru S. Chandrasekhara, Research Professor
Department of Mechanical and Aerospace Engineering
Sponsor: National University of Singapore

OBJECTIVE: To use the Naval Postgraduate School 15" (0.375m X 20" (0.5m)) water tunnel to establish the major knowledge base pertaining to maneuvering UCAV unsteady aerodynamics. The water tunnel is capable of recording unsteady aerodynamic performance on a model execution commanded motion.

SHIP STRUCTURE ANALYSES IN SUPPORT OF THE LARGE-VESSEL STOPPING PROGRAM

Jarema Didoszak, Research Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The U.S. Navy requires the capability to stop and/or restrain large, uncooperative, marine vessels without imposing catastrophic damage or deliberate loss of life. Furthermore, it is stated that the goal of the Large Vessel Stopping Program is to research innovative technologies with the potential to enhance the Navy's ability to interdict and stop a broad spectrum of maritime vessels, primarily large vessels, in open oceans and coastal regions. Specifically, this effort shall provide for the completion of engineering research and analysis complimentary to and in support of the parachute sea anchor drag system being developed by SRI International, Inc.

ACCURACY MODEL IMPROVEMENT

Morris R. Driels, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Aeronautical Systems Center

OBJECTIVE: To improve current accuracy models for various unguided and guided weapons systems.

JWS CCB SUPPORT

Morris R. Driels, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Aeronautical Systems Center

OBJECTIVE: To support the Joint Technical Coordinating Group (JTTCG) focusing on JWS CCB and GWTS CCB meetings.

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A WEAPONERING COURSE IN KOREA

Morris R. Driels, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Joint Technical Coordinating Group

OBJECTIVE: To attend the JMEM seminar and teach a three-day weaponering short-course in Seoul, Republic of Korea.

INTERFACIAL CREEP IN THIN-FILM INTERCONNECT STRUCTURES IN MICRO-SYSTEMS

Indranath Dutta, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: National Science Foundation

OBJECTIVE: In many applications of multi-component micro-systems, large shear stresses exist at interfaces between dissimilar materials, and at least one of the materials adjacent to the interface is subjected to high homologous temperatures. This enables diffusionally accommodated sliding processes (interfacial creep) to operate at the interface, impacting the deformation behavior, dimensional stability, and reliability of the component. Furthermore, thin-film interconnect structures in micro-systems often carry large electric-current densities, which drive electromigration. As interconnect dimensions shrink, interfaces become the primary path for diffusion during electromigration, potentially leading to significant interactions between interfacial diffusive fluxes due to applied stress and electromigration. Thus, depending on the direction of applied current relative to the direction of the applied shear stress, electromigration-driven interfacial diffusion may either enhance or reduce interfacial sliding. With the emerging trend towards nano-scale miniaturization of multi-material assemblies in microelectronics, MEMS and functional nano-composites, and the commensurately explosive growth in the interfacial area inside these assemblies, interfacial sliding is likely to become increasingly prominent, particularly since both thermo-mechanical and electrical loads are expected to increase in the future.

In this work, a comprehensive experimental and analytical effort is proposed to obtain fundamental mechanistic insight into interfacial creep at thin-film-substrate interfaces under thermo-mechanical, as well as thermo-mechanical-cum-electrical loads. The effort will combine creep testing with and without an applied electrical current, detailed interfacial characterization, constitutive modeling, and experimental/analytical investigations of microelectronic device structures.

The work will be of substantial fundamental importance since it will be the first-ever study of interfacial creep in thin-film systems, and also the first-ever study to investigate the interaction between stress and electric-current-driven diffusion in promoting/inhibiting interfacial sliding. The work will be of great practical importance by generating kinetics data in a number of important engineering systems with applications in the micro-systems industry, and by developing a constitutive law that can be utilized for reliability predictions. The work will be of immense technological significance if interfacial sliding were ever to become performance-limiting in future micro-systems, since it will lay a framework for exploiting the interaction between stress and electric current to mitigate sliding through design considerations.

The broader impact of the work is related to its technological relevance to the entire micro/nano-systems industry by bringing to light a new phenomenon that may become performance-limiting in a wide array of components in the future. Throughout the project, the principal investigators will work closely with industry to identify/address issues of emerging relevance. In addition to training graduate students and post-doctoral students, summer high school student interns will be hired.

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VALID CONSTITUTIVE – AND RELEVANT FAILURE – MODELS FOR SNAGCU SOLDER ALLOYS

Indranath Dutta, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Purdue University

OBJECTIVE: To develop experimentally validated constitutive models for deformation and failure of solder joints under high strain rate, creep, and electromigration conditions.

PHYSICS-BASED MODELING AND ASSESSMENT OF FLEET/FORCE SUSTAINMENT TECHNOLOGY OPTIONS

Joshua H. Gordis, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To provide continuing studies on an operational model, physics-based where possible, of various systems, both existing and proposed, for Fleet and force sustainment. This model will allow the rational assessment of candidate technologies. The model can then be used to identify technology gaps and proposed solutions. A simple computable metric is proposed in order to evaluate the relative merit of different options. In order to narrow the initial scope of the study, the research will be focused on a scenario involving sea base expeditionary maneuver forces for combat operations ashore.

ENVIRONMENTAL CHARACTERIZATION AND FIELD TESTING FOR THE U.S. SPECIAL OPERATIONS COMMAND BLUE-LIGHT SPECIAL

Anthony J. Healey, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: U.S. Special Operations Command

OBJECTIVE: To support initial field testing of the U.S. Special Operations Command Blue Light Special (BLS) underwater communications system in Monterey Bay. Using a REMUS autonomous underwater vehicle, the Naval Postgraduate School (NPS) will measure the environmental characteristics in the BLS system's operating area to assess the optical properties of the surrounding seawater. NPS will then conduct several underwater communications experiments, experiments between a fixed location and a mobile platform to measure BLS data rate as a function of range and orientation. Finally, NPS will produce a detailed after-action report summarizing the results of these experiments.

FY08 SUPPORT OF RESEARCH IN SUPPORT OF VSWMCM

Anthony J. Healey, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The center plans to continue current and expand in 2008 with the following initiatives: autonomous, underwater vehicle (AUV) obstacle avoidance; high-bandwidth communications for UAV/USV/UUV systems; support for the feature-based navigation program in mine neutralization; and distributed FBN for autonomous underwater vehicles.

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THE NAVAL POSTGRADUATE SCHOOL CENTER FOR AUTONOMOUS UNMANNED VEHICLE RESEARCH 2008 PROGRAM SUPPORT FOR THE AIR FORCE RESEARCH LABORATORY

Anthony J. Healey, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Air Force Research Laboratory

OBJECTIVE: The principal goal of the Air Force Research Laboratory's (AFRL) Project Marti is to provide information management (IM) at the tactical level using high-altitude platforms and unmanned, aerial systems (AUS). This produces the following information-flow hierarchy: information producers—small- to medium-sized UAS platforms; information consumers—tactical operators, strategic decision makers; information brokers—high-altitude platforms, such as balloons and HALE. The center's goal is to support the project's objectives. Specifically, this entails the use of the center's Scan Eagles together with the information broker platform to demonstrate the project concept.

RAMPRESSOR COMPRESSION STATIC TESTING
Garth V. Hobson, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Ramgen Power Systems, Inc.

OBJECTIVE: To provide technical expertise and testing support in the Naval Postgraduate School Gas Dynamics Laboratory for Ramgen's rampressor.

THE STATIC BOUNDARY-LAYER CONTROL EXPERIMENT
Garth V. Hobson, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Ramgen Power Systems, Inc.

OBJECTIVE: To provide testing facilities and technical expertise to perform tests on a boundary-layer control experiment.

THE TRANSONIC FAN STAGE-STEAM INGESTION STUDY
Garth V. Hobson, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: This proposal stems from a prior exposure to the problem of ingestion on the F414 engine and an awareness of the potential criticality to a single-engine aircraft, such as the Joint Strike Fighter (JSF). The transonic compressor rig (TCR) has been enhanced with a steam generator for the introduction of steam into its inlet at various flow rates. The primary objective is to obtain controlled data on the effect of steam ingestion and inlet flow distortion on stall behavior. Initial steam ingestion tests were successfully performed at up to 95% rotor speed.

THE TRANSONIC FAN STAGE-STEAM INGESTION STUDY
Garth V. Hobson, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: Measurement and test techniques that were developed during steam ingestion tests on a transonic fan stage will be used to determine the effect of inlet distortion on a scaled version of the F136 first-stage fan. The effect of steam ingestion has not been quantified on either of the Joint Strike Fighter (JSF) engines, nor has the first stage fan of the F136 engine been individually rig tested. The collaboration

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with General Electric and Rolls Royce on this project will address both these issues. The added complexity of measurement within a fan stage that includes an inlet guide vane will also be addressed during this study. The benchmark data will be used to guide the validation of codes and the establishment of best practices that ensure the accurate prediction of inlet distortion due to steam ingestion.

GREATER AUTONOMY FOR USVS IN RIVERINE ENVIRONMENTS

Douglas P. Horner, Research Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To collaborate with Stilwell (Virginia Tech) to develop the capability for an unmanned, surface vessel to operate quickly and autonomously in unknown riverine environments. The principal investigators will develop autonomous navigation algorithms and technologies to identify obstacles, both moving and non-moving, and then optimally plan and re-plan a course in real time. Developments will lead to a field demonstration at the end of year one.

THE NAVAL POSTGRADUATE SCHOOL CENTER FOR AUTONOMOUS UNMANNED VEHICLE RESEARCH 2008 PROGRAM SUPPORT FOR THE AIR FORCE RESEARCH LABORATORY

Douglas P. Horner, Research Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Air Force Research Laboratory

OBJECTIVE: The principal goal of the Air Force Research Laboratory (AFRL) Project Marti is to provide information management (IM) at the tactical level using high-altitude platforms and unmanned, aerial systems (UAS). This produces the following information flow hierarchy: information producers—small- to medium-sized UAS platforms; information consumers—tactical operators, strategic decision makers; and information broker—high-altitude platforms, such as Balloons and HALE. The center's goal is to support the project's objectives. Specifically, this entails the use of the center's Scan Eagles together with the information broker platform to demonstrate the project concept.

NON-LINEAR SURVEILLANCE AND DOCKING STATION RENDEZVOUS WITH AUVS

Douglas P. Horner, Research Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: This proposal addresses the need for advanced navigation equipment for two autonomous, underwater vehicles (AUV). The goal is to conduct research into collaborative, non-linear search behaviors for multiple AUVs, and to develop methodologies for deployment and recovery of AUVs to and from a mobile docking station. The Naval Postgraduate School Center for Autonomous Vehicle Research develops greater autonomy in unmanned systems and gives students challenging engineering projects that are directly linked to Naval operations. This proposal addresses how an inertial navigation system and cross body thrusters would enhance the center's research ability in three areas: collaborative, non-linear search strategies, mobile docking-station deployment and recovery, and feature-based navigation. These research areas are expected to significantly improve several Naval mission areas, including organic mine countermeasures, intelligence, surveillance, and reconnaissance (ISR), and maritime interdiction operations.

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UNMANNED SURFACE VEHICLE RIVERINE OBSTACLE DETECTION AND AVOIDANCE

Douglas P. Horner, Research Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To develop and field test the following: surface and subsurface sensing modalities to detect navigational obstacles, a unified stochastic surface and subsurface map of the environment suitable for real-time navigation, and agile planning and control approaches that enable USV operations over a uniquely wide operating envelope and that encompass the requirements of long-range path planning and exploration and local trajectory generation and obstacle avoidance.

VSWMCM PROGRAM MANAGER ONR32

Douglas P. Horner, Research Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To conduct autonomous vehicle research in support of VSWMCM.

AIR-VOLUME CAPACITY AND TIME-CRITICAL COORDINATION OF MULTIPLE, UNMANNED, AERIAL VEHICLES

Isaac I. Kaminer, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: This proposal addresses an issue critical to U.S. Navy (USN) planners and current and future USN unmanned, aerial vehicle (UAV) operators, namely, the question of airspace-volume capacity that can be populated by multiple UAVs performing single or multiple missions in a littoral environment in support of the warfighter. The answer to this question must include more than just the number of UAVs, but also the desired paths for performing the required mission(s) and staying inside the air box, and the algorithms needed to track these paths and coordinate between multiple UAVs by using the underlying wireless network. In fact, coordination constraints must be included in the initial, air-volume capacity/path planning step. The types of missions considered in this research include intelligent surveillance and reconnaissance, coordinated terrain following, and support of small SEAL teams, to name a few.

FLIGHT VALIDATION OF METRICS-DRIVEN ADAPTIVE CONTROL

Isaac I. Kaminer, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: NASA Langley Research Center

OBJECTIVE: To develop a complete framework for the design and experimental validation of the metrics-driven adaptive-control algorithms using unmanned platforms available at the Naval Postgraduate School and NASA.

GREATER AUTONOMY FOR USVS IN RIVERINE ENVIRONMENTS

Isaac I. Kaminer, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To collaborate with Stilwell (Virginia Tech) to develop the capability for an unmanned, surface vessel to operate quickly and autonomously in unknown riverine environments. The principal investigators will develop autonomous navigation algorithms and technologies to identify obstacles, both

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moving and non-moving, and then optimally plan and re-plan a course in real-time. Developments will lead to a field demonstration at the end of year one.

THE NAVAIR FATIGUE (P3-ASIWG) PROJECT

Ramesh Kolar, Research Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVE: To attend the NAVAIR P3-ASIWG Conference, present a paper, and discuss the research issues on fatigue methodology for the P-3 and other air vehicles with the sponsor. To develop plans for hosting the next meeting.

THE NAVAIR P3 FATIGUE AND SUSTAINMENT PROJECT

Ramesh Kolar, Research Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Naval Air Systems Command

OBJECTIVE: To visit with the Naval Air Station Whidbey Island P3-Wing 10 Division to discuss fatigue issues of aircraft BUNO331. The P3-Program Office at the Naval Air Systems Command is coordinating this effort.

DAMAGE DETECTION IN A COMPOSITE INTERFACE THROUGH CARBON NANOTUBE REINFORCEMENT

Young W. Kwon, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To qualify the capability of using electrical conductivity of percolated carbon-nanotube networks to detect damage at interfaces in composite structures. To quantify the potential of such an approach to “hot-spot” monitoring, this research will include a parameter-based experimental investigation of carbon-nanotube networks to detect and monitor damage.

THE EFFECTS OF FLUID-STRUCTURE INTERACTION ON DYNAMIC RESPONSES OF COMPOSITE STRUCTURES: EXPERIMENTAL AND NUMERICAL STUDIES

Young W. Kwon, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

SUMMARY: To understand the dynamical response of composite structures immersed in water that is subjected to impact or impulse loading. Furthermore, dynamical responses of the structures in water and air will be compared to enhance the understanding of the effects of fluid-structure interaction on marine composite structural behaviors through both experimental and numerical studies. In addition, a parametric study will be undertaken to identify the major factors that influence composite structures in terms of fluid-structure dynamics.

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A STUDY OF COMPOSITE SCARF AND METAL-COMPOSITE HYBRID JOINTS

Young W. Kwon, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To assist the Naval Surface Warfare Center-Carderock Division (NSWCCD) team for Advanced Hull Materials and Structures Technology (AHM&ST), particularly in the technology area of bonded composite joints and metal-composite hybrid joints. Test specimens replicating joint configurations and surface preparations will be fabricated and tested by the Naval Postgraduate School.

A STUDY OF COMPOSITE AND METAL JOINTS FOR SHIP APPLICATION

Young W. Kwon, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: To support the Structures and Composite Division of the Naval Surface Warfare Center-Carderock Division (NSWCCD) for Advanced Hull Materials and Structures Technology (AHM&ST), particularly in the technology area of composite and metal joints for ship applications. Experimental and/or computational work will be conducted to determine and/or evaluate the effective joining techniques. This is a continuing work from previous years.

THE EFFECTS OF STRESS STATE ON THE DEFORMATION AND FAILURE MECHANISM IN SUPERPLASTIC AA5083

Terry R. McNelley, Distinguished Professor

Department of Mechanical and Aerospace Engineering

Sponsor: University of Texas at Austin

OBJECTIVE: To assess the grain boundary sliding to solute drag creep transition during deformation under various stress states, including uniaxial and biaxial conditions; and to compare experimental and model textures for this transition. Microtexture analysis of cavity initiation and growth will be extended to determine the contribution of grain boundary sliding under various stress states; this will include a three-dimensional examination of growing cavities in relation to the dispersed constituent particles. Mechanical testing of thermo-mechanically processed DC cast material will be conducted to assess the role of grain refinement in the transition.

THE FORMATION OF HIGH-ANGLE GRAIN BOUNDARIES AND THE EVOLUTION OF TEXTURE DURING SEVERE PLASTIC DEFORMATION PROCESSING OF ALUMINUM ALLOYS

Terry R. McNelley, Distinguished Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To evaluate the hypothesis that high-angle boundaries form from the interface between blocks or bands having lattice orientations that are variants of characteristic shear-texture components during severe plastic deformation (SPD) by equi-channel angular pressing (ECAP). The influence of alloy constitution, ECAP processing parameters, and stability of microstructures during post-processing annealing will also be evaluated. Mechanical testing will provide data to assess the roles of grain refinement by ECAP and alloy constitution on properties.

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MICROSTRUCTURE EVOLUTION AND MICROSTRUCTURE-PROCESSING-PROPERTY RELATIONSHIPS IN FRICTION STIR PROCESSING OF NIA1 BRONZE

Terry R. McNelley, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To conduct an experimental investigation into mechanisms of microstructure evolution and microstructure-mechanical property relationships associated with friction stir processing of NiAl bronze propeller materials. Factors leading to low ductility in processed material will be of primary concern.

MICROSTRUCTURE-PROCESSING-PROPERTY RELATIONSHIPS IN FRICTION STIR PROCESSING OF NIAL BRONZE

Terry R. McNelley, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To conduct a three-year investigation into the mechanisms underlying microstructure evolution during multi-pass friction stir processing (FSP) of NiAl bronze and the related processing microstructure property relationships in these materials. The roles of process variables, including step-over distance, will be identified, and models for processes of microstructure transformation and strengthening will be developed.

THE STRUCTURE AND PROPERTIES OF LCS ALUMINUM WELDS BY NEW FRICTION STIR WELDING

Terry R. McNelley, Distinguished Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To evaluate and compare microstructures and mechanical properties for welds produced by conventional (single-sided) and recently developed, bobbin-tool, friction stir welding (FSW) methods in integrally stiffened, aluminum panels for structural applications in the Littoral Combat Ship (LCS) and other systems.

ADVANCED MARINE GAS TURBINE TECHNOLOGY PROGRAMS

Knox T. Millsaps, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: This project supports the Advanced Technology Group Manager (Code 91) in the Marine Gas Turbine Branch of NAVSEA for the life-cycle support of the ship service and main propulsion gas turbines. This work includes providing analysis of test data and methodologies for the detection and localization of compressor stall of the GE LM2500 and engineering support for online compressor washing evaluation.

LABORATORY-SCALE PRODUCTION, OPTIMIZATION, AND FUELS CHARACTERIZATION OF ALGAE-DERIVED, BIO-DIESEL BLENDS

Knox T. Millsaps, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: This project supports the Office of Naval Research initiative to investigate and characterize the fuel and combustion properties of algae-derived bio-fuels. The Naval Postgraduate School (NPS) will

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create and manage a program to develop laboratory-scale production of algae-derived bio-diesel fuels and to create protocols for the measurement of characteristics of the pure oils and diesel blends delivered to NPS by subcontractors. Conventional ASTM diesel-fuel tests and advanced droplet and combustion measurements will also be made. Requirements and protocols for certification and use in a variety of Naval facility applications will be outlined. Advice on improving fuel characteristics and blend composition will be provided to ONR.

SCIENCE, MATHEMATICS, AND RESEARCH FOR TRANSFORMATION (SMART) DEFENSE EDUCATION

Knox T. Millsaps, Professor
Department of Mechanical and Aerospace Engineering and
DoD Executive Agent for SMART Scholarship-for-Service Program
Sponsor: Office of the Secretary of Defense

DESIGN AND IMPLEMENTATION OF ULTRA-MOBILE, SELF-ALIGNING ANTENNA SYSTEMS FOR OPTIMIZED RADIO-FREQUENCY (AARF) LINK-BUDGET ANALYSIS FOR USE BETWEEN A GROUND STATION AND AN UNMANNED, AERIAL-VEHICLE PLATFORM

Michael Keith Mishoe, Jr.-Captain, United States Marine Corps
Department of Information Sciences
Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To conduct a system-level test and evaluation of a prototyped SAA device. The primary objective is to determine the functional performance envelope and tactical mobility of a cost-effective, man-portable SAAS equipped with a global positioning system (GPS), a microprocessor, and a digital compass. To accomplish this objective, a robust test and evaluation plan will be produced. Using this test plan, the device will be base-lined in the laboratory facilities of the Naval Postgraduate School. The system will then be field-tested in various operating environments and scenarios spanning domestic and international locations as part of the COASTS 2008 international field-experimentation program.

This research is part of the Cooperative Operations and Applied Science and Technology Studies (COASTS) 2008 Project. Students and faculty from the Naval Postgraduate School, supported by Office of Naval Research reservists and numerous commercial partners and hosted by international organizations from South East Asia, will conduct a series of experiments and demonstrations in the United States, Thailand, Greece, and possibly Indonesia. The experiments and scenarios are based around setting up a rapidly deployable, wireless network for information sharing between the United States and regional partners. Several different platforms and technologies will be utilized to provide situational awareness across the network, including UAVs. The two primary network protocols that will be used are the Institute of Electrical and Electronics Engineers (IEEE) 802.11 and the IEEE 802.16.

AN ELECTRIC-SHIP TRADE-OFF ENVIRONMENT FOR MISSION EFFECTIVENESS

Fotis A. Papoulias, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To provide a methodology and tool development for conducting a systematic set of early design trade-offs for all-electric naval ships. The proposed work will utilize domain-level experts at the Naval Postgraduate School (NPS), especially with regards to mission effectiveness and weapon system characterization. The results of the methodology and tools that will be developed will be tested and used in various NPS educational activities, such as the Total Ship Systems Engineering Program.

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PHYSICS-BASED MODELING AND ASSESSMENT OF FLEET/FORCE SUSTAINMENT TECHNOLOGY OPTIONS

Fotis A. Papoulias, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To provide an operational model (physics-based where possible) of various systems, both existing and proposed, for Fleet and force sustainment. This model will allow the rational assessment of candidate technologies. The model can then be used to identify technology gaps and proposed solutions. A simple computable metric is proposed to evaluate the relative merit of different options. In order to narrow the initial scope of the study, this research will be focused on a scenario involving sea-base expeditionary-maneuver forces for combat operations ashore. Additional scenarios will be studied in follow-on studies.

SHIPS: DEVELOPMENT OF A SHIP-HUMAN INTEGRATED PERFORMANCE SYSTEM

Fotis A. Papoulias, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To provide a methodology and tool development for conducting a systematic set of design trade-offs with regards to manning considerations and human performance of Naval ships. The proposed work will utilize domain level experts at the Naval Postgraduate School (NPS), especially with regards to mission effectiveness, motion analysis, and human performance modeling. The results of the methodology and tools that will be developed will be tested and used in various NPS educational activities, such as the Total Ship Systems Engineering Program.

AN AGILE ATTITUDE-CONTROL SUBSYSTEM FOR NANOSATS BASED ON CONTROL MOMENT GYROSCOPES: A FLIGHT PROTOTYPE

Marcello Romano, Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To design, develop, and test a fully functional, flight prototype for a CubeSat attitude-control subsystem based on miniaturized control moment gyroscopes actuators (CMGS). This innovative subsystem will enable agile attitude slewing and accurate pointing/tracking for spacecraft made of multiple (2-5+) CubeSat units. These attitude control capabilities, currently unavailable for CubeSats, are essential for several critical missions (e.g., earth imaging, optical communications, and situational awareness applications). The proposed attitude-control subsystem is entirely contained in the volume of less than 1 liter and has a total mass of less than 1 kilogram. The design specifications include a 3 sigma pointing accuracy <0.01 deg, maximum torque >10 mNm along each axis, momentum storage >24 mNms along each axis, 0.4 W typical power need, and a 1.2 W peak power need at max torque. The proposed attitude-control subsystem uses miniaturized control moment gyroscopes, which have been used for decades for large, agile, high-performance spacecraft, and are advantageous versus reaction wheels for having a higher torque/power and torque/volume ratio. The deliverables include a fully functional engineering development unit (EDU) at a scale of 1:1 of the attitude-control subsystem, performance tests, and control software. The EDU is considered to be a prototype for a flight unit. The proposed research is intended to contribute to the following three functional capabilities among the National Reconnaissance Office priorities by enabling the development of new spacecraft concepts (such as TINYScope): persistent surveillance, monitor known threats, and innovative capabilities.

AUTONOMOUS GUIDANCE AND CONTROL OF A SPACECRAFT APPROACHING A TUMBLING OBJECT FOR DOCKING OR OTHER PROXIMITY OPERATIONS

Marcello Romano, Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Air Force Research Laboratory

OBJECTIVE: To support the modeling and simulation efforts of spacecraft dynamics and control within RVES and RVSU. This research focuses on the autonomous guidance and control of a spacecraft that is approaching a tumbling, resident space object (RSO) for close inspection or docking. The research is broken into the following high-level tasks: 1) problem formulation and solving for the optimal solution; 2) synthesis of sub-optimal controls capable of real-time implementation; and 3) construction of models and simulations to compare developed controllers.

A PROTOTYPE FLIGHT UNIT OF AN AGILE NANOSATELLITE ATTITUDE-CONTROL SYSTEM: DEVELOPMENT, TESTING, AND INTEGRATION WITH AN EXPERIMENTAL NANOSATELLITE

Marcello Romano, Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Air Force Research Laboratory

OBJECTIVE: A prototype flight unit of a novel nanosat attitude-control system based on control moment gyroscopes will be developed. The preliminary design of this system has already been developed by Dr. Romano and his team. This new attitude-control system will first be tested in the lab by using a new three-axis simulator test-rig; then, flight testing will be conducted onboard the nanosat mission scat++, which is under development at the Naval Postgraduate School and will be launched onboard the space shuttle at the end of 2010. The proposed attitude-control system consists of four miniaturized, single-gimbal control-moment gyroscopes. The system is entirely contained in the volume of less than 1 liter and has a total mass of less than 1 kilogram. Each CMG consists of a flywheel, actuated by a brushless DC motor. The flywheel is encased in a gimbal structure. A second brushless DC motor with integrated, harmonic, drive gear allows the gimbal and flywheel to rotate about an axis normal to the rotation-axis of the flywheel. Slip rings are used for electrical connection of the flywheel DC motor. The gimbal motor case is rigidly connected to the spacecraft. A non-contact magnetic encoder is used to accurately measure the angular position of the gimbal with respect to the spacecraft.

TINYSCOPE: TINY AGILE SPACECRAFT FOR EARTH IMAGING APPLICATIONS FROM LEO

Marcello Romano, Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: National Reconnaissance Office

OBJECTIVE: To conduct an eighteen-month follow-up of the ongoing TINYSCOPE (Tactical Imaging Nanosat Yielding Small-Cost Operations for Persistent Earth-Coverage) research project, which is investigating the concept of using a nanosat-class, three-axis, stabilized spacecraft for earth imaging applications. In particular, the proposed phase two effort aims to develop a phase BIC detailed design for a nanosat spacecraft capable of three-meter ground resolution from an orbital altitude of 500 km and having high-attitude slewing agility. A fully functional engineering developed unit (EDU) of the spacecraft, at a scale of 1:1, will be designed and integrated using both commercial, off-the-shelf and custom-made components. In addition, a new and unique three-axis attitude-control simulator will be developed in order to test (in a lab environment) the attitude navigation and control of TINYSCOPE and other nanosat spacecraft.

The conceptual design for an optional enhanced-resolution system (one meter from 500 km) will also be conducted, as well as the conceptual mission design for a constellation of several TINYSCOPE spacecraft, with the goal of reaching a very short (one hour) revisit time. This research is intended to bring TINYSCOPE close to a flight-ready condition. Building upon the research, the principal investigators

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expect to develop a flight-ready TINYScope unit and conduct an orbital test during a phase three follow-up project. This research is intended to significantly contribute, at a low-cost/high-return level, to the following four functional capabilities among the National Reconnaissance Office's priorities: persistent surveillance, monitor known threats, innovative capabilities, and information on-demand.

ADVANCED OPTIMAL CONTROL STUDIES

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: To analyze certain key problems arising in a cross-section of disciplines that may be prime for an application of advanced, optimal-control methods. The proposed research is exploratory in nature, with the exception that a few problems will be identified that hold the potential for an order of magnitude increase in performance.

ADVANCED OPTIMAL GUIDANCE ALGORITHM DEVELOPMENT

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: The Boeing Company

OBJECTIVE: To produce demonstrations and comparisons of numerical trajectory modeling/optimization algorithms as applied to the guidance of aerospace vehicles. To share modeling details to enable extension to other applications (source code and MATLAB scripts).

CMG EXPERIMENTS

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Secretary of the Air Force/FMBMB-AFOY

OBJECTIVE: To implement and experiment with a real-time optimal-control algorithm that was shown to theoretically outperform existing CMG controllers. The implementation and experimentation will be done in several stages with different options.

THE DEVELOPMENT OF A RAPID MISSION DESIGN TOOL FOR THE CEV

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: NASA Johnson Space Center

OBJECTIVE: To collaborate with Johnson Space Center engineers towards the goal of developing a rapid mission design tool for the CEV.

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IN SITU SPACECRAFT SYSTEM IDENTIFICATION USING FAKE MEASUREMENTS

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: National Reconnaissance Office

OBJECTIVE: To explore the use of fake measurements to extend the applicability of an unscented Kalman filter to system ID both “blue” and “red” spacecraft (this project is related to the 2008 research entitled “Adversarial Spacecraft System ID”).

MINIMUM-FUEL RELATIVE-MOTION TRAJECTORIES NEAR AN UNCOOPERATIVE TARGET

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: For an imaging spacecraft to provide truly persistent surveillance capability, the satellite should be in a higher orbit, requiring large-aperture, lightweight, deployable mirrors in the range of 10-20 meters in diameter. The objective of this research program is to improve adaptive-optics control techniques for a flexible, deployable, space-mirror surface and beam control and to minimize image aberrations. This is a continuing project. During phase one, the major emphasis was on developing an adaptive-optics testbed and demonstrating the ability to correct image aberrations by using adaptive optics. The testbed has two adaptive-optics systems and one jitter-control system.

During phase two, the emphasis was on three tasks: development of a six-segment, 16-inch-diameter, CFRP segmented mirror; improved adaptive-optics control techniques; and development of a phase diversity sensor. A parabolic, segmented mirror with a 48-inch focal length was procured. Based on the experimental results on control methods, the modal method with combined integral and gradient feedback control was best for minimizing image aberrations. Flexible dynamics were simulated by injecting a sinusoidal disturbance into the input signal. A phase diversity sensor was developed to correct piston and tip/tilt error of the segments for phase three.

During phase three, the segmented mirror and phase diversity sensor will be implemented on the adaptive testbed. Three actuators on the back of each segment will be added. Algorithms will be developed to determine piston and tip/tilt error from the phase diversity sensor. A redundant spacing calibration technique will be also developed to calculate piston and tip/tilt error. The principal investigators will evaluate the application of multi-input multi-output (MIMO) with robust control for the surface control problem. Various multivariable robust-control techniques, such as the loop-shaping method and weighted mixed-sensitivity controller synthesis, etc., will be investigated.

A NEW APPROACH FOR FAST WAVEFRONT RECONSTRUCTION

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: National Reconnaissance Office

OBJECTIVE: Fast and accurate wavefront reconstruction is a major technical challenge in adaptive optics. Based on preliminary research carried out at the Naval Postgraduate School, a pseudospectral approach to wavefront reconstruction that holds the potential for significantly enhancing wavefront approximation is proposed. If successful, the results of this project will have a ripple effect in considerably enhancing image quality in segmented mirror telescopes.

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OPTIMAL CONTROL EXPLORATIONS

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: To explore the optimal control framework for the integrated control, optimization, and autonomous operations of a number of problems that arise in the engineering and operations of space systems, autonomous ground vehicles, autonomous aerial vehicles, and other autonomous vehicles that are of interest to the military and intelligence communities. The proposed approach is exploratory in nature, and if successful, is expected to have a long-term, sustained impact on the development of military systems.

A PSEUDOSPECTRAL APPROACH FOR THE CONTROL AND OPTIMIZATION OF LARGE, SEGMENTED MIRRORS

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: To develop and analyze a pseudospectral framework for the integrated control and optimization of the very large-scale control system (thousands of sensors and actuators) found in the design of large telescopes based on segmented mirror technology. The proposed approach is exploratory in nature, and if successful, is expected to have a long-term, sustained impact on the development of extremely large telescopes. The proposed research parallels the techniques that are currently being implemented on the segmented mirror demonstrator.

PSEUDOSPECTRAL FEEDBACK CONTROL FOR SPACE APPLICATIONS

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To develop and analyze a pseudospectral framework for the integrated control and optimization of the very large-scale control system found in the design of large telescopes based on segmented mirror technology. The proposed approach is exploratory, and if successful, is expected to have a long-term sustained impact in the development of extra-large telescopes.

PSEUDOSPECTRAL METHODS FOR OPTIMAL CONTROL AND ESTIMATION WITH APPLICATIONS TO SPACE

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To develop a unified theoretical foundation for pseudospectral methods in the optimal control and estimation of general nonlinear systems; and to apply the method to achieve real-time optimal control of space systems. The goal is to advance the state-of-the-art by solving optimal control and estimation problems that are not solvable using existing methods.

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THE ROBOTIC ARM LAB

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: Secretary of the Air Force/FMBIB-AFOY

OBJECTIVE: To continue to develop the Robotic Arm Laboratory at the Naval Postgraduate School to explore advanced control methods for path-planning and collision-avoidance of multi-link robotic arms.

THE TALON DARK MIRROR

I. Michael Ross, Professor

Department of Mechanical and Aerospace Engineering

Space Systems Academic Group

Sponsor: Air Force Tactical Exploitation of National Capabilities

OBJECTIVE: To implement and experiment a real-time optimal-control algorithm. The implementation and experimentation will be done in several stages with different options.

LCS CLASS SHIP-SHOCK MODELING AND SIMULATION USING DYSMAS CODE

Young S. Shin, Distinguished Emeritus Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Naval Sea Systems Command

OBJECTIVE: To provide modeling and simulation development, analysis, and support for shock and vibration analysis of the Littoral Combat Ship (LCS) class using Dysmas code. This includes performing FEM modeling of the two hull variants of the LCS class in support of the required survivability analysis; performing validation and verification of the LCS FEM models as specifically prepared for shock and vibration analysis for both LCS hull variants; and identifying potential problem areas related to the survivability of the LCS hull variants.

A PAYLOAD-DERIVED POSITION-ACQUISITION SYSTEM FOR PARACHUTE RECOVERY SYSTEMS

Oleg A. Yakimenko, Research Professor

Department of Mechanical and Aerospace Engineering

Sponsor: U.S. Army Yuma Proving Ground

OBJECTIVE: To develop, test, and support novel software that allows for obtaining inertial coordinates and attitude of a test article during the entire trajectory, from aircraft-exit to ground-impact, based on the IMU data provided initialized at deployment by an aircraft.

**DEPARTMENT OF
MECHANICAL AND AEROSPACE
ENGINEERING**

**2009
Faculty Publications
and Presentations**

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**DEPARTMENT OF
METEOROLOGY**

**PHILLIP A. DURKEE
CHAIR**

METEOROLOGY

OVERVIEW:

Since its arrival in Monterey from the U.S. Naval Academy in 1948, the Department of Meteorology has continued to provide graduate-level instruction in the science of meteorology and its application in support of military operations. To maintain expertise and provide support to student theses, the faculty performs research in the Navy and Air Force relevant areas of synoptic and dynamic meteorology, remote sensing, numerical modeling, tropical meteorology, boundary layer meteorology, and environmental effects.

In 1959, the Naval Oceanographic Command moved its numerical prediction center to Monterey as a new operational command - Fleet Numerical Weather Central (now the Fleet Numerical Meteorology and Oceanography Center-FNMOC). The Navy chose to move FNMOC to Monterey to take advantage of the presence of NPS and its large assembly of science faculty, who are intimately familiar with Navy operational problems in meteorology and oceanography. For similar reasons, the Navy Environmental Prediction Research Facility (now the Marine Meteorology Division of the Naval Research Laboratory (NRL) Monterey) moved to Monterey in 1971. This further augmentation of meteorological and oceanographic scientists in Monterey has made it the center of naval environmental science.

In 2003, under an agreement between the Air Force and Navy Secretaries, Air Force Weather officers returned to NPS and now receive an MS or PhD in Meteorology. These officers have reinvigorated classrooms and laboratories with new perspectives and ideas for improving weather support of DoD missions.

The Department of Meteorology serves a broad spectrum of research interests supported by ONR, NSF, NASA, NOAA, NGA, and other DoD and civilian national research sponsors.

CURRICULA SERVED:

- Meteorology
- Meteorology and Physical Oceanography
- Electronic Warfare

DEGREES GRANTED:

- Master of Science in Meteorology
- Master of Science in Meteorology and Physical Oceanography
- Doctor of Philosophy in Meteorology

RESEARCH THRUSTS:

Synoptic, Mesoscale, and Coastal Meteorology:

Distinguished Professor Russell Elsberry, Professor Wendell Nuss, Professor Patrick A. Harr, Professor Michael Montgomery, Assistant Professor Richard Moore, Assistant Professor Karl Pfeiffer (Military Faculty), and Research Associate Michael Bell

Numerical Weather Prediction (NWP):

Associate Professor Joshua Hacker, Assistant Professor Rebecca Stone (Military Faculty), and Research Associate Hway-Jen Chen

Environmental Analysis and Visualization:

Research Associate Mary Jordan

Air-Sea Interactions:

Professor Qing Wang, Research Professor Kenneth Davidson, Research Associate Paul A. Frederickson, Research Associate Professor Peter Guest, and Assistant Professor Rebecca Stone (Military Faculty)

METEOROLOGY

Satellite and Ground-Based Remote Sensing:

Professor Philip Durkee, Research Associate Kurt Nielsen, and Research Associate Michael Bell

Tropical Meteorology:

Distinguished Professor Russell Elsberry, Distinguished Professor Chih-Pei Chang, Professor Patrick A. Harr, Professor Michael Montgomery, Research Associate Hway-Jen Chen, Research Associate Michael Bell, and Research Associate Stephanie Zick

Tropical Cyclone Motion:

Professor Patrick A. Harr, Professor Michael Montgomery, Research Associate Michael Bell, and Research Associate Stephanie Zick

Boundary Layer Meteorology:

Research Professor Kenneth Davidson, Professor Qing Wang and Research Associate Professor Peter Guest

Climate Dynamics:

Distinguished Professor Chih-Pei Chang, Research Associate Hway-Jen Chen, Research Associate Professor Tom Murphree

Atmospheric Factors in EM/EO Propagation:

Professor Kenneth Davidson, Research Associate Professor Peter Guest, and Research Associate Paul Frederickson

Polar Meteorology:

Research Associate Professor Peter Guest

RESEARCH FACILITIES:

George J. Haltiner Laboratory for Weather Analysis and Prediction:

The Haltiner Lab is designed to support complex data acquisition, analysis, and decision-making capabilities for a variety of environmental problems and DoD applications.

IDEA Laboratory:

The Interactive Digital Environmental Analysis Laboratory has Silicon Graphics workstations specifically designed and funded for instruction. The lab computers are used to analyze and display real-time satellite data and numerical model output.

RSL:

The Remote Sensing Laboratory operates a SeaSpace NOAA satellite receiver that collects and processes environmental data in support of atmosphere and ocean analysis.

SAFL:

The Synoptic Analysis and Forecasting Laboratory uses a suite of computers and advanced display devices to provide local and global, real-time, meteorological data and numerical products for instruction and research in operational weather forecasting.

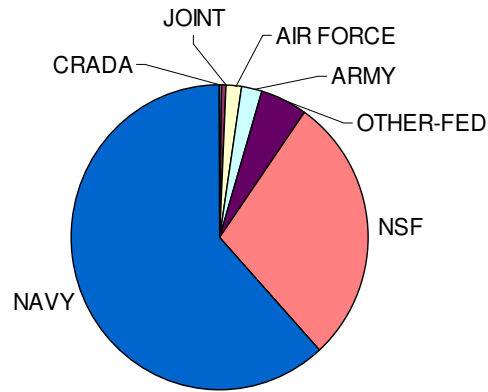
ABLML:

The Atmospheric Boundary Layer Measurements Laboratory provides information from a special, near-coastal, observation site at Fort Ord in support of instruction and research in boundary layer and coastal meteorology. Present instrumentation includes two radar wind profilers, an automatic surface weather station, and rawinsonde systems.

METEOROLOGY

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Meteorology is provided below:



Size of Program: \$3.8M

METEOROLOGY

Philip A. Durkee
Professor and Chair
831-656-2516
durkee@nps.edu

Michael M. Bell
Research Associate
831-988-6092
mmbell@nps.edu

Chih-Pei Chang
Distinguished Professor
831-656-2840
cpchang@nps.edu

Hway-Jen Chen
Research Associate
831-656-3788
hjchen@nps.edu

Kenneth L. Davidson
Professor
831-656-2309
kldavids@nps.edu

F. Anthony Eckel
Maj, USAF, Military Faculty
Assistant Professor
831-656-3430
faeckel@nps.edu

Russell L. Elsberry
Distinguished Professor
831-656-2373
elsberry@nps.edu

Paul A. Frederickson
Research Associate
831-656-2407
pafreder@nps.edu

Peter S. Guest
Research Professor
831-656-2451
pguest@nps.edu

Robert L. Haney
Professor Emeritus
831-656-7571
rlhaney@nps.edu

Patrick A. Harr
Professor
831-656-3787
paharr@nps.edu

Mary S. Jordan
Research Associate
831-656-7571
jordan@nps.edu

Michael T. Montgomery
Professor
831-656-2296
mtmontgo@nps.edu

Richard Moore
Assistant Professor
831-656-1041
rwmoor1@nps.edu

Tom Murphree
Research Associate Professor
831-656-2723
murphree@nps.edu

Kurt E. Nielsen
Research Associate
831-656-1026
kenielse@nps.edu

Wendell A. Nuss
Professor
831-656-2308
nuss@nps.edu

Karl D. Pfeiffer
Lt Col, USAF, Ph.D.
Military Faculty
Assistant Professor
831-656-3635
kdpfeiff@nps.edu

Rebecca E. Stone
CDR, USN, Military Faculty
Program Officer for METOC
831-656-3269
restone@nps.edu

Vicki Taber
LCDR, USN
Military Faculty
Lecturer
831-656-7712
vltaber@nps.edu

Qing Wang
Professor
831-656-7716
qwang@nps.edu

Carlyle H. Wash
Professor
831-656-7776
wash@nps.edu

Forrest R. Williams
Senior Lecturer Emeritus
831-656-3274
fwilliams@nps.edu

Roger T. Williams
Professor Emeritus
831-656-2296
rtwillia@nps.edu

CONVECTION AND SHEAR FLOW IN TROPICAL CYCLONE DEVELOPMENT AND INTENSIFICATION

Chih-Pei Chang, Distinguished Professor

Department of Meteorology

Sponsor: Office of Naval Research

OBJECTIVE: To study the dynamic processes of tropical cyclone (TC) development in the western North Pacific through field observational data and theoretical modeling.

SUMMARY: The data for this study was collected by the NRL P-3 aircraft near typhoon Sinlaku 2008 (W15, 2008), which became a named typhoon on 00Z, September 9, 2008. It reached its maximum intensity on 18 UTC, September 10, with maximum wind up to 125 knots and minimum center pressure 929 hPa. Then it slowly weakened with wind speed dropping to 35 knots on 00 UTC, September 17. Afterwards, it began its second phase of intensification with the maximum wind reaching 70 knots and minimum SLP pressure of 970 hPa on 06 UTC, 19 September.

NRL P-3 aircraft (research flight #14m RF014) sampled the outer and inner rainband around 02 UTC on 18 September. The P-3 approached the rainband from the eastern side of Sinlaku, then circled counterclockwise to the northern and western portions, and finally broke out of the rainband at the southwestern side of the typhoon. The P-3 spent about 20 minutes on this 3/4 part of the entire circulation and collected valuable data for this study. Using the dual-Doppler technique, the three-dimensional wind field on both sides of the flight track was obtained wherever there was echo. The radar reflectivity pattern showed several rainbands associated with the typhoon and wrapped into the center transferring the moisture flux into the inner eye wall. At the ranges between 41 and 51 km, a rainband which seemed to be standing along without wrapping directly into the center was used to compute the filamentation time.

Rozoff, et al. (2006), theorized that the formation of a moat region between concentric eyewalls may be partially caused by the strong filamentation effects associated with large core vorticity. In the past, only synoptic scale data were available to study the characteristic of the time-scale for growth. The high-resolution NRL P-3 dual-Doppler radar observations provided a unique opportunity to calculate this time scale. The filamentation is defined as

$$\tau_{fi} = \begin{cases} 1/\sqrt{S_1^2 + S_2^2 - V^2}, & \text{if } S_1^2 + S_2^2 - V^2 > 0 \\ 0, & \text{if } S_1^2 + S_2^2 - V^2 < 0 \end{cases},$$

where $S_1 = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$, $S_2 = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$, and $V = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$ are stretching deformation, shearing

deformation and vorticity, respectively. These terms are computed using the dual-Doppler radar wind at each grid point.

RESULTS: The distribution of radar reflectivity with respect to filamentation time within the 51 km range at different heights from the sea level was examined. For a maximum frequency near 30-35 dBZ and a filamentation time around 15 minutes: 1) several spiral rainbands with high reflectivity were found to wrap into the center, possibly transporting the enthalpy flux into the inner eye wall; 2) existence of a rapid filamentation zone (i.e., filamentation time smaller than 30 minutes) in a region between a radius of 5 km and 50 km; 3) of all the data analyzed, the filamentation time, vorticity field, and vertical motions were well correlated positively with the convective dBz values; 4) within the radius of 50 km, the filamentation time (the deep convection dBz counts) in general increased with the radius from the typhoon center; and 5) large (small) variability of radar reflectivity dBz counts was observed in the region of small (large) filamentation time – the large variability of dBz in a rapid filamentation zone may be an indication that some deep convections are weakened by the filamentation dynamics (shear deformation).

PUBLICATION:

Kuo, H.-C., Chang, C.-P., Yang, Y.-T., and Jiang, H.-J., "Western North Pacific Typhoons with Concentric Eyewalls," *Monthly Weather Review*, 137, 3758–3770, 2009.

KEYWORDS: Tropical Meteorology, Tropical Cyclones

MONSOON DISTURBANCES IN SOUTHEAST ASIA AND ADJACENT SEAS

Chih-Pei Chang, Distinguished Professor

Department of Meteorology

Sponsor: Office of Naval Research

SUMMARY: To study the behavior and predictability of monsoon disturbances in Southeast Asia and adjacent seas.

VOLCANIC ASH CLOUD FORECASTING

Chih-Pei Chang, Distinguished Professor

H.J. Chen, Research Associate

Department of Meteorology

Sponsor: Naval Research Laboratory

OBJECTIVE: To forecast the transport of size-resolved volcanic ash and distinguish the location of it from SO₂.

SUMMARY: The aerosol module of the Naval Research Laboratory (NRL) COAMPS was adapted to simulate the volcanic ash transport in the previous project year. That version treated the volcanic ash as a tracer with dry deposition and rain wash-out processes. However, the sedimentation effect, which strongly depends on the particle size, was not considered. This year, this project further adapted the COAMPS to include this effect and applied it on different sizes of ash.

This research focused on studying the impact of the sedimentation effect to the spatial distribution of the forecasted ash. The ash particles were divided into five bins with a radius from 1 μ m to 40 μ m. Particles smaller than 1 μ m have similar behavior to 1 μ m particles, so they are all allotted to the smallest bin. Particles larger than the upper bound (40 μ m) fall out from the air very fast and are insensitive to the weather processes so they are not considered in this study. Generally speaking, the particles of interest are those that have a lifetime of 12 hours or longer.

The adapted model was applied to the Kasatochi eruption of 7 August 2008. In this case study, it was found that the horizontal distribution of total ash mass load showed good agreement with the observed cyclonic pattern. The largest particles (40 μ m radius particles) had fall velocities up to 0.8 m/s and reached the ocean in six hours. The next two smaller bins began to reach the ocean in 12 and 24 hours, respectively. The two smallest bins had fall velocities of three and two orders of magnitude less than the largest particles, respectively, and showed virtually no effects of sedimentation.

The spatial distributions of forecasted ash were quite different from bin to bin. The differences were caused by vertical wind shear and the rate of ground deposition. The larger particles sedimented faster than smaller particles so they fell to the lower level and were transported by lower level wind. They were also removed from air faster than smaller ash since they touched the ground sooner.

The spatial distribution of ash was also distinguished from SO₂, which had provided false alarm to pilots, since SO₂ has no sedimentation effect.

PRESENTATION:

Westphal, D.L. and Chen, H.-J., "Size-Resolved Forecasting of Volcanic Ash Plumes," *Eos Trans. AGU*, 90(52), Fall Meet. Suppl., Abstract V23F-06, 2009.

KEYWORDS: Volcanic Ash, Aerosol

METEOROLOGY

EXPLOITING KNOWLEDGE OF ATMOSPHERE IMPACTS ON RADAR DETECTION AND SIGNATURE IDENTIFICATION, AND ON AIS TRANSMISSION FOR MARITIME DEFENSE AND SECURITY

Kenneth L. Davidson, Research Professor

Peter S. Guest, Associate Research Professor

Department of Meteorology

Sponsor: NPS Marine Domain Security Research (MDSR) Program

OBJECTIVE: To improve the predictions of radar and AIS signal ranges and target identification by exploiting knowledge of the atmospheric and surface conditions. The focus and field campaign are on coastal vessels that are potential threats to the U.S. and U.S. assets abroad.

The AIS effort involves collecting and collating AIS reception data from West Coast receiver locations for possible impact by atmosphere conditions. Collection has arisen through collaboration with persons in the Naval Postgraduate School (NPS) Ocean Acoustics Laboratory (C. Miller), who have collateral interests. Information from Bodega Bay, Pescadero, San Luis Obispo, Port Sur, and the Naval Postgraduate School (NPS) receiving stations will be examined. The Eastern Pacific High affects coverage from these differently. AIS reception data will be collated for evaluation of atmosphere impact. Recently obtained AIS tracks illustrate why there is potential for such a study. For example, “exemplary” day’s receptions (September 24th) from the NPS AIS network have been identified. Each ship track is plotted as a separate color, with the MBNMS boundary in grey.

PUBLICATIONS:

Davidson, K. and T. Huynh, “Field Tests of Coastal Surveillance ‘System of Systems’,” 6th NPS/TDS/LLNL Security Workshop on Globalization and Maritime Security, Marriott Crystal Gateway Hotel, Crystal City, Virginia, 20-12 July 2008.

Davidson, K.L., Frederickson, P.A., and Huynh, T.V., “NPS System-of-Systems Exploitation of Knowledge of Atmospheric and Ocean Surface Impacts for MIO and Maritime Security,” White Paper prepared for NORTHCOM, CNMOC (Commander Navy Meteorology and Oceanography Command), 9 pp., February 2009.

THESIS DIRECTED:

O’Marr, Erin E., “Atmosphere Effects on Signal Propagation in Adverse Environmental Conditions: A Validation of the Advanced Refractive Effects Prediction System with COASTS Demonstrations,” Master’s Thesis, Naval Postgraduate School, September 2008.

KEYWORDS: Marine Domain Security, EM Detection and AIS Data

PERFORMANCE SURFACE BASED ON OPERATIONAL ASSESSMENT OF METOC IMPACT ON SUBMARINE VULNERABILITY TO RADAR DETECTION

Kenneth L. Davidson, Professor

Department of Meteorology

Sponsor: Space and Naval Warfare Systems Command

SUMMARY: Performance surfaces that incorporate and integrate multi-source high-resolution airflow and surface descriptions data with RF/EO propagation models for battlespace on demand support of non-acoustic ASW missions.

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USE OF THE ATMOSPHERE DETECTION EFFECTS PREDICTION TOOL (ADEPT) FOR THE REAL-TIME ASSESSMENT OF SUBMARINE DETECTION VULNERABILITY AND IO EFFECTIVENESS

Kenneth L. Davidson, Research Professor
Paul A. Frederickson, Research Associate
Department of Meteorology
Sponsor: Office of Naval Research (NWDC and NIOC)

OBJECTIVE: To evaluate and formulate methods to measure, analyze, quantify, and visualize how various changes in meteorological conditions impact electromagnetic (RF) waves with respect to IO operations. This objective supports the EXPLAN09 EW improvement plan by identifying tactical EW variables concerning environmental conditions, and impact determination for planning and executing EA, particularly in maritime situations.

SUMMARY: The technology-based methods apply real-time atmosphere and ocean surface properties, predicted properties by physical and numerical models, calculated sensor performance impacts by radar propagation models, and displays for presenting impacting conditions. The following five steps were performed with combined radio and METOC data and models: 1) determine the impact of buoy measured features on RF and relate CONOPS-allowable METOC data to IO impact assessment; 2) assess transfer of weather data, e.g., solution that includes surface platforms, weather prediction centers, climatology, and tactical operations centers; 3) apply/integrate Naval Postgraduate School physical METOC models in EM effects programs; 4) generate and incorporate 4-D fields of refraction in propagation models; and 5) document impact assessment model performance in real-time using steps 1-5 in follow-on field-tests.

Performance impact and impact assessment documentation are being met by reports that describe the test operations, the test results with regard to impact, the application of operational data, and the design of an assessment system. In summary, the documentation and reporting will be guides to IO based on MBNR performance/environmental conditions analysis that will correlate decreases in performance of the MBNR to environmental factors, and will lead to the design of operational assessment methods.

KEYWORDS: COMMS Detection, Atmospheric Effects, Radio-Frequency Propagation, Evaporation Duct

SATELLITE ANALYSIS GRADUATE STUDIES SUPPORT

Philip A. Durkee, Professor and Chair
Department of Meteorology
Sponsor: Naval Research Laboratory

OBJECTIVE: To support remote sensing studies using composite satellite observations.

THE TARGET AREA METOC AUTOMATION PROJECT

Philip A. Durkee, Professor and Chair
Department of Meteorology
Sponsor: Naval Oceanographic Office

OBJECTIVE: To support Commander, Naval Meteorology and Oceanography Command in completing the target area METOC (TAM) automation project.

VALIDATION OF SAM SENSOR MEASUREMENTS

Philip A. Durkee, Professor and Chair
Department of Meteorology
Sponsor: National Reconnaissance Office

SUMMARY: This proposal is classified.

METEOROLOGY

IMPROVED TROPICAL-CYCLONE WEIGHTED-MOTION VECTOR CONSENSUS TRACK PREDICTION

Russell L. Elsberry, Distinguished Research Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: To research a new approach to consensus track forecasting, both for a deterministic model and for an ensemble track forecast approach that will provide a measure of uncertainty for each scenario.

BUOY/METOC DATA COLLECTION SUPPORT TO IEEE 802 RADIO (SEA LANCET) FIELD TESTS

Paul A. Frederickson, Research Associate
Department of Meteorology
Sponsor: Space and Naval Warfare Systems Center-Pacific

SUMMARY: To recover an instrumented buoy that has been used as an at-sea test platform off San Diego during the last two years for a new radio (Sea Lancet) being developed under a Phase II SBIR; to perform data analysis on the collected observations; and to prepare the buoy for further at-sea tests.

MARINE CLIMATIC PARAMETERS FOR EM PROPAGATION

Paul A. Frederickson, Research Associate
Department of Meteorology
Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To investigate means to improve parameterizations of marine atmospheric-refractive effects on microwave frequencies. These parameterizations need to be representative of marine surface-layer effects for predicting the performance of EM systems in both open ocean and coastal environments, and ultimately for assessing the ranges at which targets can be detected.

METEOROLOGICAL MEASUREMENTS IN SUPPORT OF A PASSIVE IMAGING SYSTEM FOR MEASURING ATMOSPHERIC SCATTERING IN A MARINE ENVIRONMENT

Paul A. Frederickson, Research Associate
Department of Meteorology
Sponsor: High Energy Laser Joint Technology Office

OBJECTIVE: To obtain atmospheric and sea surface data from an instrumented land MET-station and from a buoy off San Diego concurrently with multispectral scattering imager measurements obtained by the Marine Physical Laboratory of the Scripps Institution of Oceanography (MPL/SIO), for the purposes of analyzing and supporting analyses by MPL, of the environmental impacts on air-sea horizon contrasts and air radiance gradients.

SUMMARY: Meteorological data were successfully collected throughout 2009 from an instrumented MET-station on Point Loma. These data have undergone quality assurance and have been provided to the MPL/SIO. In April 2009, the Naval Postgraduate School Department of Meteorology research buoy was deployed off Point Loma to provide at-sea measurements of near-surface meteorological conditions and also ocean surface temperature and wave measurements. These data were transferred by radio telemetry back to the shore station and underwent quality assurance. The data collected were of excellent quality and have been provided to MPL/SIO for their further analyses efforts. At the end of the year the buoy was still deployed off Point Loma and was functioning optimally. These data are critical to assess the environmental impacts on high energy laser (HEL) performance in a ship self-defense application.

KEYWORDS: Multi-Spectral Scattering Imager, MSI, High Energy Laser, HEL, Air-Sea Horizon Contrast

METEOROLOGY

METEOROLOGICAL MEASUREMENTS IN SUPPORT OF A PASSIVE IMAGING SYSTEM FOR MEASURING ATMOSPHERIC SCATTERING IN A MARINE ENVIRONMENT

Paul A. Frederickson, Research Associate
Department of Meteorology
Sponsor: Air Force Research Laboratory

SUMMARY: To obtain atmospheric and sea surface data from an instrumented land MET-station and from a buoy off San Diego concurrently with multispectral scattering and imager measurements obtained by the Marine Physical Laboratory of the Scripps Institution of Oceanography (MPL/SIO), for the purpose of analyzing and supporting analyses by MPL, of the environmental impacts on air-sea horizon contrasts and air radiance gradients.

METOC: IMPACT DETERMINATION AND IO PERFORMANCE ASSESSMENT – A MULTI- BAND NETWORK RADIO

Paul A. Frederickson, Research Associate
Department of Meteorology
Sponsor: Office of Naval Research

SUMMARY: To evaluate and formulate methods to measure, analyze, quantify, and visualize how various changes in meteorological conditions impact electromagnetic (RF) waves with respect to IO operations. This objective supports the EXPLAN09 EW improvement plan by identifying tactical EW variables concerning environmental conditions, and impact determination for planning and executing EA, particularly in maritime situations.

A PASSIVE IMAGING SYSTEM TO MEASURE ATMOSPHERIC SCATTER AND CFLOS

Paul A. Frederickson, Research Associate
Department of Meteorology
Sponsor: High Energy Laser Joint Technology Office

SUMMARY: To obtain atmospheric and sea surface data from an instrumented land MET-station and from a buoy off San Diego concurrently with multispectral scattering imager measurements obtained by the Marine Physical Laboratory of the Scripps Institution of Oceanography (MPL/SIO), for the purpose of analyzing and supporting analyses by MPL, of the environmental impacts on air-sea horizon contrasts and air radiance gradients.

ATMOSPHERIC EFFECTS ON TNT/CBE OPERATIONS AND TARGET DETECTION

Peter S. Guest, Associate Research Professor of Meteorology
Department of Meteorology
Sponsor: USSOCOM–NPS Cooperative Field Experimentation Program

OBJECTIVE: To provide environmental situational awareness for simulated battlefield environments and improve target detection models.

SUMMARY: The Naval Postgraduate School Department of Meteorology performed and prepared in situ 4D meteorological data at McMillan Field, Camp Roberts, California, as part of the Cooperative Based Experimentation (CBE) Program (which was renamed in 2009 from the Tactical Network Topology (TNT) Program). This effort was a series of four experiments that took place at Camp Roberts, California. The principal investigator (PI) performed several experiments involving improvised explosive devices (IEDs) in a collaboration called the Tactical Assessment and Live Experimentations (TALE). The TALE experiments utilized Army soldiers and Marines who have direct experience with IEDs in Iraq and Afghanistan. The soldiers would drive Humvees and other vehicles in simulated IED-attack situations. The settings of the three experiments in FY09 were a flat field, a hilly region, and an urban (actually abandoned buildings) environment. The principal investigator's (PIs) role was to measure environmental factors that might affect

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radio transmission ranges jamming and from triggering devices. A suite of instruments was developed to measure temperature and humidity at six levels in the atmosphere, and soil temperature at four levels, including the surface, soil moisture, all radiation components, and wind speed. There were significant differences in RF detection ranges as the environment changed. The PIs also supported unmanned remote aircraft (UAV) flights and various simulated battlefield scenarios during four field programs in 2009. Several McMillan field collection systems were used: a meteorological tower located beside the runway, twice daily upper-air rawinsonde soundings, photography measurements, and IR surface temperature probes. Web-based weather information was also compiled. Each morning, and throughout the day as needed, a weather briefing was provided to all participants by the air boss or others. Visibility studies using bar charts and targets of opportunity were also performed. These studies also involved the use of target detection models, which take into account the influence of optical turbulence and human physiological factors. A great value of this work was the opportunity to work with operational special forces personnel to get feedback on the value of our products and to learn ways that we can benefit future operations.

PUBLICATIONS:

Guest, P.S., "CBE/TNT09-3 Quick Look Report," Naval Postgraduate School, Monterey, California, 2009.

Guest, P.S., "CBE09-4 Quick Look Report," Naval Postgraduate School, Monterey, California, 2008.

Guest, P.S., "CBE10-1 Quick Look Report," Naval Postgraduate School, Monterey, California, 2008.

Guest, P.S., "TNT09-2 Quick Look Report," Naval Postgraduate School, Monterey, California, 2009.

KEYWORDS: Environmental Effects, Target Detection, Special Forces

ATMOSPHERIC PERFORMANCE SURFACES FOR SUBMARINE PERISCOPE DETECTION

Peter S. Guest, Associate Research Professor of Meteorology

Paul A. Frederickson, Research Associate

Department of Meteorology

Sponsor: Space and Naval Warfare Systems Command (PMW-120)

OBJECTIVE: To produce and validate atmospheric performance surfaces (ATPS) for the radar detection of submarine periscopes and other targets that take into account the impact of environmental conditions on radar system performance based on COAMPS forecasts.

SUMMARY: Efforts were continued in collaboration with the Naval Research Laboratory, Monterey (NRL-MRY), to develop and integrate the various components necessary for producing operational atmospheric performance surfaces (ATPSs) of increasing usefulness and fidelity for non-acoustic ASW missions. An algorithm was developed and tested to smoothly blend near-surface refractivity profiles produced by the Naval Postgraduate School Bulk Surface-Layer Model onto the bottom of the COAMPS refractivity profiles. This step is critical to accurately resolve and characterize the evaporation duct in ATPS, which has a dominant impact on near-surface radar propagation. Validation efforts were also successful in comparing the radar detection ranges predicted by ATPS against actual detection ranges observed during the RIMPAC 2008 Fleet Exercise to determine the accuracy of ATPS. Collaboration continues with NRL-MRY to implement new and improved capabilities into the ATPS system.

PUBLICATION:

Frederickson, P., Guest, P., and Davidson, K., "Atmospheric Performance Surfaces (ATPS)," *Office of Naval Research FY09 6.2/6.4 Technical Program Reviews*, Naval Research Laboratory, Monterey, California, 14-16 April 2009.

KEYWORDS: Radar Detection, Atmospheric Performance Surface, Radio-Frequency Propagation, Evaporation Duct

METEOROLOGY

MODELING IMPROVISED EXPLOSIVE DEVICE DETECTION AND DEFEAT METHODS IN VISIBLE, IR, AND RADIO FREQUENCIES

Peter S. Guest, Associate Research Professor

Department of Meteorology

Sponsor: Naval Postgraduate School, Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: More accurate and reliable detection of improvised explosive devices (IEDs) by aircraft and ground forces by understanding environmental effects on the performance of visible and infrared imaging systems and the behavior of radio waves.

SUMMARY: From 16 August to 2 September 2009, the principal investigator (PI) participated in Panama City Near Earth Propagation Tests (PCNEPT) at the Naval Surface Warfare Center Panama City (NSWC PC), Florida. This experiment consisted of two phases; phase one occurred over a moist field, while phase two was in the NSWC harbor. For the moist field phase, four meteorological profile towers and soil properties were placed adjacent to a short-range radio-frequency propagation test. The signal strength and phase shifts of various frequency radio waves were measured as a function of distance (5-100 m) and height (approximately 5 to 80 cm). The variations in the radio characteristics were compared with the detailed environmental measurements. For phase two, a similar set-up was done in a harbor environment with radio propagation paths occurring over open water. All of the measurements were successfully performed, and some of these data were used for U.S. Navy LT Samuel Mason's Master's thesis. Because the tide changed the elevation of the radio receivers above the water surface, it was possible to quantify the effect of elevation on propagation strength. Even though the transmit and receive antennas were always line-of-site, there was a significant increase in signal strength as elevation increased due to increasing destructive RF interference with surface-reflected radiation at lower levels. A wide variety of environmental measurements were performed, including measurements of temperature and humidity at six levels in the atmosphere, soil temperature at four levels (including the surface, soil moisture, all radiation components, wind speed), and direct turbulent fluxes. For phase two, water temperature at six depths and water salinity were also measured. The variations in RF signal due to elevation changes had a dominate effect on RF strength compared to the other environmental measurements.

PUBLICATIONS:

Monthly JIEDDO reports.

THESIS DIRECTED:

Bieger, D., "Verification of Buried Improvised Explosive Device (IED) Target Detection Capability in Target Acquisition Weapons Software (TAWS)," Master's Thesis, Naval Postgraduate School, March 2009 (SECRET).

KEYWORDS: Harbor Defense, Detection Range, Atmospheric Effects

PREDICTING THE CHANGING ARCTIC ENVIRONMENT

Peter S. Guest, Research Associate Professor

Department of Meteorology

Sponsor: Naval Research Laboratory

OBJECTIVE: To improve the understanding of the physical processes in the Arctic, where significant climate changes have recently been observed; and based on this new understanding, to develop new physical parameterizations that will better forecast the weather in this critical region.

METEOROLOGY

TACTICAL NETWORK TOPOLOGY MARINE INTERDICTION OPERATIONS ENVIRONMENTAL EFFECTS RESEARCH

**Peter S. Guest, Associate Research Professor of Meteorology
Department of Meteorology**

Sponsor: Naval Postgraduate School Maritime Defense and Security Research

OBJECTIVE: To provide support by assessments of environmental impacts on the Maritime Interdiction Operations (MIO). To develop an integrated tool for incorporating various environmental data sources into models of radar, visible and infrared detection of target vessels, people and weapons.

SUMMARY: There were two TNT MIO field programs in FY09. A primary focus of the MIO experiments was to evaluate the use of networks, advanced sensors, and collaborative technology for MIO. Each morning of the Tactical Network Topology (TNT) MIO projects, the principal investigator (PI) presented weather and sea state briefs to all participants. This was used to support various vessel and land-based communication systems. For one of the projects, the PI deployed a meteorological measurement system on the Alameda County Sheriffs Boat using instrumented masts and operated continuously during the entire time-collection period. These data and internet sources were used as input radar, visible and infrared detection of target vessels, people, and weapons. Plots showing the results of these models were placed in workspaces that were available to all participants and updated continuously. Much practical scientific information was obtained on the various factors that affect target detection.

KEYWORDS: Marine Interdiction, Homeland Security, Target Detection

WEATHER ASSESSMENT ON OPERATIONS IN AFGHANISTAN

**Peter S. Guest, Associate Research Professor
Department of Meteorology**

Sponsor: Naval Postgraduate School, Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To provide information and guidance for planners that have made anti-improvised explosive device (IED) operations more effective and less costly.

SUMMARY: This work developed an operational product that is used to make long-term predictions of the performance of an anti-IED system at a particular location in Afghanistan. This product was based on several years of meteorological data collected at this location. This was a relatively straightforward and immediately applicable study. All the expected objectives were met.

PUBLICATIONS:

A detailed report is available on SIPRNET. The title and body are CLASSIFIED.

KEYWORDS: IEDs, Weather Impacts

PREDICTABILITY, PROBABILISTIC PREDICTION

**Joshua P. Hacker, Associate Professor of Meteorology
Department of Meteorology**

Sponsor: Naval Postgraduate School Research Initiation Program

OBJECTIVE: To advance the state of the science and lay a foundation of future proposals in predictability and data assimilation, including the specific topics of covariance localization, parameter estimation, and data assimilation in the planetary boundary layer. The focus will be on research with the Data Assimilation Research Testbed (DART) using the Weather Research and Forecast (WRF) Model, the Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS™), and other models appropriate for specific topics.

SUMMARY: Several challenging problems with lower-atmosphere predictability and prediction remain open. Ensemble data assimilation offers both a paradigm and a tool for advancing the state of the science in predictability and prediction. Data assimilation (DA) is an approach that can, in theory, provide an optimal combination of models and observations. As such, it allows the study of predictability and prediction errors in a system constrained by observations. Because ensemble DA uses a flow-dependent background-error covariance estimated from a sample of predicted pdf (namely, an ensemble prediction), it is hoped that the complex horizontal and vertical covariances in the planetary boundary layer (PBL) can be used to define errors. Model inadequacy and sampling error currently prevent optimal DA in the PBL, but both can be studied and possibly mitigated in an ensemble DA system.

KEYWORDS: Predictability, Boundary Layer, Ensemble, Data Assimilation

EXTRA-TROPICAL TRANSITION OF TROPICAL CYCLONES OVER THE WESTERN NORTH PACIFIC – PHYSICAL CHARACTERISTICS, DOWNSTREAM IMPACTS, AND PREDICTABILITY

Patrick A. Harr, Professor

Russell L. Elsberry, Distinguished Professor

Department of Meteorology

Sponsor: National Science Foundation

OBJECTIVE: In this research, the characteristic structure of an extratropical transition (ET) event is placed in a framework of three regions defined as: 1) the decaying tropical cyclone core, 2) the tropical cyclone-midlatitude interface, and 3) the midlatitude impact region. Specific objectives include: 1) increase understanding of the dependence of the occurrence, amplitude, and extent of the downstream response to an ET event on the character of the interaction between the decaying tropical cyclone and the midlatitude circulation into which it is moving; 2) define the relative roles of the decaying tropical cyclone characteristics and the midlatitude flow characteristics in downstream development with an ET event; and 3) assess the impact on predictability of downstream development due to improved representation of the structural characteristics associated with an ET event.

SUMMARY: A major component to this project was the field program titled the “THORPEX Pacific Asian Regional Campaign (T-PARC),” which was conducted in 2008. During 2009, the downstream impact of the extratropical transition of TY Sinlaku, which occurred during T-PARC, on operational global model forecasts was investigated using a local eddy kinetic energy budget. Additionally, experiments were conducted to relate sensitivity of forecasts of the extratropical transition of TY Tokage (2005) to data distribution. Several studies of numerical forecasts of the tropical cyclones that occurred during T-PARC were conducted. Diagnostic analyses of deterministic forecasts of tropical cyclones over periods of 12 h – 120 h from four operational global models were conducted, as were 32-day predictions from the ensemble prediction system of the European Center for Medium Range Weather Forecasts. An analysis of the COAMPS-TC forecasts of tropical cyclones that occurred during T-PARC was also completed. Finally, simulations of the extratropical transition of TY Sinlaku, using the high-resolution Advanced Weather Research Forecast (A-WRF) Model, have begun.

PUBLICATION:

Harr, P.A., and Dea, J.M., “Downstream Development Associated with the Extratropical Transition of Tropical Cyclones over the Western North Pacific,” *Monthly Weather Review*, Vol. 137, No. 4, pp.1295 – 1319, 2009.

PRESENTATIONS:

Harr, P.A., “The Extratropical Transition of Tropical Cyclones: Downstream Impacts and Predictability,” Second Predictability and Dynamics of Weather Systems in the Atlantic-European Sector (PANDOWAE) Workshop, Murnau, Germany, 16-18 February 2009 (keynote invited).

<http://www.pandowae.de/en/newsevents/2nd-workshop>

Harr, P.A., "The THORPEX Pacific Asian Regional Campaign and Affiliated Programs over the Western North Pacific: Objectives, Strategies, and Accomplishments," First Planning Workshop, THORPEX North Atlantic Waveguide and Downstream Experiment (T-NAWDEX), Edring, Germany, 19-20 February 2009 (invited).

<http://www.pandowae.de/en/newsevents/t-nawdex-workshop>

Harr, P.A., "The THORPEX Pacific Asian Regional Campaign and Affiliated Programs over the Western North Pacific: Objectives, Strategies, and Accomplishments," The International Association of Meteorology and Atmospheric Sciences Assembly, Montreal, Quebec, Canada, 19-29 July 2009 (invited).

<http://www.moca-09.org/e/documents/IAMAS2009Program15w.pdf>

Harr, P.A., "Typhoon Sinlaku during T-PARC: Sensitivity of Re-Intensification and Downstream Development to the Track Following Recurvature," International Workshop on Advancement of Typhoon Track Forecast Technique, Tokyo, Japan, 30 November - 2 December 2009 (invited).

http://www.mri-jma.go.jp/Topics/TyphoonWorkshop_Tokyo_20091130-1202/index.html

Harr, P.A. and Moore, J.M., "The THORPEX Pacific Asian Regional Campaign and Affiliated Programs over the Western North Pacific: Objectives, Strategies, and Accomplishments," Third THORPEX Science International Science Symposium, Monterey, California, 14-18 September 2009.

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/TTISS_program_august31.pdf

Sanabia, E. and Harr, P.A., "The Impact of Typhoon Sinlaku on the Northern Hemisphere Midlatitudes during T-PARC," Third THORPEX Science International Science Symposium, Monterey, California, 14-18 September 2009.

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/TTISS_program_august31.pdf

THESIS DIRECTED:

Trevino, R.A., "The Large-Scale Environment during the Tropical Cyclone Structure 2008 and THORPEX Pacific Asian Regional Campaign," Master's Thesis, Naval Postgraduate School, 87 pp., September 2009.

AN IMPROVED WIND-PROBABILITY-ESTIMATION PROGRAM

Patrick A. Harr, Professor

Department of Meteorology

Sponsor: Colorado State University

OBJECTIVE: The collaborators each agree to perform specific tasks. The Naval Postgraduate School (NPS) will be responsible for the following tasks: 1) calculate Goerss Predicted Consensus Error (GPCE) values from the model forecast archive; 2) develop the GPCE database and identify the best database input methods; and 3) assist in data analysis and evaluation of the best methods to estimate track error.

Colorado State University (CSO) will be responsible for the following tasks: 1) provide technical expertise to execute and improve the Wind Probability Estimation Program; 2) modify the existing MC model to incorporate the GPCE input; and 3) optimize GPCE information and coordinate with the Tropical Prediction Center to run a parallel version in real-time.

NPS and CSO will be responsible for the following joint tasks: 1) finalize the best methodology to utilize the GPCE input; 2) optimize and modify the existing MC model to improve the model speed and the probabilistic skills; and 3) evaluate the modified Wind Probability Estimation Program and identify areas of improvement.

METEOROLOGY

PROBABILITY FORECASTS OF A TROPICAL CYCLONE TRACK

Patrick A. Harr, Professor
Department of Meteorology
Sponsor: 45th U.S. Air Force Weather Squadron

OBJECTIVE: To examine the spread-versus-skill relationship among forecasts of tropical cyclone (TC) track and intensity produced by operational numerical forecast models. Statistical techniques are used to establish the distribution of ensemble spread and forecast errors. The goal is to then investigate whether improvement to the current National Hurricane Center (NHC) operational product for producing probabilistic forecasts of TC wind distributions could be made by further examining the distributions of track errors it draws upon to calculate probabilities. If it is possible to use different distributions for different situations, the probabilistic output may be more accurate. This could lead to a reduction of the massive costs of overly cautious evacuations when forecast confidence is high, or even save lives by expanding the evacuation zone when forecast confidence is low.

SUMMARY: During the initial stages of this project, ensemble-based forecast tracks from a variety of operational weather centers were obtained from the THORPEX Interactive Grand Global Ensemble data base archive center at the European Center for Medium Range Weather Forecasts. These data reside in CXML format, and are converted for general use in statistical analysis and display. THORPEX (The Observing Research and Predictability Experiment) is a World Meteorological Organization project directed at improving forecasts of high-impact weather out to 14 days. The use of a wind distribution model versus intensity values provided by the numerical models is being examined. In this continuing project, current efforts are defining the strategy for incorporating the more dynamic error distributions into the probability model framework to assess the refinements made to the probability swaths of hurricane-force winds.

WESTERN NORTH PACIFIC TROPICAL CYCLONE FORMATION AND STRUCTURE CHANGE IN TCS08 AND TCS08 EXPERIMENT SUPPORT

Patrick A. Harr, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: This research has three components: improvement in understanding of the formation of tropical cyclones through a comprehensive observational and numerical modeling study focusing on the mesoscale contributions within specific synoptic-scale circulations in the western north Pacific; improvement in understanding how the outer wind structure is related to the conditions during the formation stage and then are modified via external forcing mechanisms using both TCS08 observations and numerical modeling; and providing leadership and facilitating the TCS08 field experiment activities and in the post-TCS08 data.

SUMMARY: A diagnostic analysis of forecasts of tropical cyclone formation from operational global models was defined and implemented (Elsberry, et al., 2009a). Also, the skill of 32-day forecasts of tropical cyclone events from the 51-member ensemble prediction system of European Center for Medium-Range Weather Forecasts (ECMWF) was assessed during the period of 5 June through 25 December 2008 (Elsberry, et al., 2009b). Analysis of COAMPS-TC forecasts of tropical cyclones that occurred during the TCS-08 field program was completed (Hensley, 2009).

The structural evolution of Typhoon (TY) Sinlaku during TCS-08 was examined as it weakened under extreme vertical wind shear then re-intensified to typhoon intensity (Sanabia and Harr, 2009) prior to undergoing extratropical transition. The impact of aircraft observations on the definition of the surface wind field associated with the typhoons that occurred during TCS-08 was assessed relative to remotely-sensed data (Havel, 2009). Experiments were conducted to relate sensitivity of forecasts of the extratropical transition of TY Tokage in 2005 to data distribution (Anwender, et al., 2009). The large-scale circulation over the tropical and midlatitude North Pacific region during TCS-08 was examined as an anomalous period of reduced monsoon activity by Trevino (2009). The structure of a tropical circulation system was defined by examining high-resolution radar data and aircraft data obtained during flights during the TCS08

field program (Malvig, 2009). Finally, a workshop was conducted to provide principal investigators information on the data management associated with TCS-08.

PUBLICATIONS:

Anwender, D., Jones, S., Leutbecher, M., and Harr, P., “Sensitivity Experiments for Ensemble Forecasts of the Extratropical Transition of Typhoon Tokage,” *Quart. J. Royal Meteor. Soc.*, 136, 183-200, 2009.

Elsberry, R.L., Clune, W.M., Elliott, G., and Harr, P.A., “2009a: Evaluations of Global Model Early Track and Formation Predictions during the Combined TCS08 and T-PARC Field Experiment,” *Asia-Pacific Journal of Atmospheric Sciences*, 45, 357-373, 2009.

Elsberry, R.L., Jordan, M.S., and Vitart, F., “2009b: Predictability of Tropical Cyclone Events on Intraseasonal Timescale with the ECMWF Monthly Forecast Model,” *Asia-Pacific J. Atmos. Sci.*, (in press).

PRESENTATIONS:

Elsberry, R.L., Montgomery, M.T., Raymond, D., Black, P., Hawkins, J., Harr, P.A., et al., “The Tropical Cyclone Structure-2008 (TCS-08) Program: Objectives on Tropical Cyclone Formation, Intensification, and Structure Change,” Third THORPEX Science International Science Symposium, Monterey, California, 14-18 September 2009.

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/TTISS_program_august31.pdf

Hawkins, J., Black, P., Harr, P.A., and Elsberry, R.L., “High Altitude Observations Enabling 3-D Pre-Genesis Monitoring,” First Tropical Cyclone Structure-2008 Science Workshop, Monterey, California, 29-30 October 2009.

http://www.met.nps.edu/~harr/tcs08/TCS-08_Workshop_agenda_for_web.htm

Sanabia, E.R., and Harr, P.A., “Re-Intensification of TY Sinlaku Prior to Extratropical Transition,” First Tropical Cyclone Structure-2008 Science Workshop, Monterey, California, 29-30 October 2009.

http://www.met.nps.edu/~harr/tcs08/TCS-08_Workshop_agenda_for_web.htm

THESES DIRECTED:

Havel, P.J., “Surface Wind Field Analyses of Tropical Cyclones during TCS-08: Relative Impacts of Aircraft and Remotely-Sensed Observations,” Master’s Thesis, Naval Postgraduate School, September 2009.

Hensley, J.M., “A Verification of the COAMPS-TC Model Prediction Typhoon Nuri,” Master’s Thesis, Naval Postgraduate School, September 2009.

Malvig, S.C., “Analysis of a Non-Developing Tropical Circulation System during the Tropical Cyclone Structure (TCS-08) Field Experiment,” Master’s Thesis, Naval Postgraduate School, December 2009.

Trevino, R.A., “The Large-Scale Environment during the Tropical Cyclone Structure 2008 and THORPEX Pacific Asian Regional Campaign,” Master’s Thesis, Naval Postgraduate School, September 2009.

METEOROLOGY

CMG: ANALYSIS OF TRANSPORT, MIXING, AND COHERENT STRUCTURES IN HURRICANE INTENSITY

Michael T. Montgomery, Professor

Department of Meteorology

Sponsor: National Science Foundation

OBJECTIVE: The work to be carried out during the remaining years of this grant will comprise an array of analyses examining transport and mixing processes in the hurricane core region, in addition to new methods that emerge during the course of this work. The research will be carried out by the principal investigator at his new institution and the other senior team members (Kirby, Schubert, and Danglemayer) and their graduate students and researchers at their respective institutions.

COLLABORATIVE RESEARCH: DYNAMIC AND THERMODYNAMIC CONTROL OF TROPICAL INTENSITY IN SHEARED ENVIRONMENTS

Michael T. Montgomery, Professor

Department of Meteorology

Sponsor: National Science Foundation

OBJECTIVE: The principal investigators propose to undertake a comprehensive investigation of the physics of the interaction between tropical cyclones and the sheared flow in which they are embedded, focusing on the mutual operation of dynamic and thermodynamic processes. It is hypothesized that tropical cyclones are weakened by the injection of low-entropy middle-level air into the vortex core by vortex Rossby waves excited by the interaction between the vortex and environmental shear flow. The emphasis on the mutual importance of dynamical and thermodynamical processes departs from most previous investigations, which have focused almost exclusively on direct dynamical effects. Evidence from an operational tropical-cyclone-intensity prediction model is presented that dry air injection is indeed an important factor in tropical-cyclone-intensity change. This research would have a direct path to improved prediction of tropical cyclones through the improvement of this operational model.

The starting point of this research will be two key theoretical developments that have matured over the previous decade: the quantitative theory of thermodynamic control of hurricane intensity, and the theory governing the generation, behavior, and wave/mean flow interaction of vortex Rossby waves. From these points, an extended theory will be developed for the generation and maintenance of vortex Rossby waves as a consequence of the interaction between vortices and ambient shear flow, addressing as well the rate at which these waves flux passive tracers in and out of the vortex core region. This will be used as guidance in modifying the thermodynamic cycle to account for dry air injection at middle levels by the vortex Rossby waves. Having developed this theoretical framework, the principal investigators will test it using a suite of models, focusing on fully three-dimensional simulations at high resolution using a non-hydrostatic model. The theory will be modified based on the results of these tests. Finally, this theory will be used to develop a parameterization of Rossby wave-induced fluxes of low entropy air, for use in axisymmetric models.

ON THE MARSUPIAL THEORY OF TROPICAL CYCLOGENESIS WITHIN TROPICAL WAVE AND MONSOON TROUGH ENVIRONMENTS: A MULTISCALE OBSERVATIONAL, MODELING, AND THEORETICAL STUDY

Michael T. Montgomery, Professor

Department of Meteorology

Sponsor: National Science Foundation

OBJECTIVE: This research pioneers a comprehensive synthesis of synoptic scale, mesoscale, and cloud scale phenomena to determine how pre-typhoon/hurricane proto vortices are created and able to survive adverse environmental influences from dry air intrusions and/or vertical shear.

METEOROLOGY

A MULTISCALE STUDY OF TROPICAL CYCLONE FORMATION, STRUCTURE CHANGE, AND PREDICTABILITY IN THE WESTERN NORTH PACIFIC REGION AND TCS08 EXPERIMENT SUPPORT

Michael T. Montgomery, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: To develop an improved observational, theoretical, and numerical weather prediction understanding of the role of bottom-up and top-down mesoscale mechanisms in the tropical cyclone formation process in the West-PAC region; and to better understand and quantify the role of vortex-intrinsic processes in the predictability and structure change of West-PAC tropical cyclones.

PRE-DEPRESSION INVESTIGATION OF CLOUD-SYSTEMS IN THE TROPICS (PREDICT)

Michael T. Montgomery, Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: PRE-Depression Investigation of Cloud-Systems in the Tropics (PREDICT) is a focused observational field campaign to investigate both the structure and evolution of tropospheric, wave-like disturbances in the tropics and sub-tropics and the sub-synoptic and mesoscale processes operating within the waves that contribute to the formation of tropical depressions in the Western Atlantic sector. This new field project aims to test new scientific hypothesis as part of the “marsupial paradigm” of the tropical cyclone formation.

QUANTIFYING THE EFFECTS OF VORTICAL HOT TOWERS AND VORTEX ROSSBY WAVES ON TROPICAL CYCLONE INTENSIFICATION

Michael T. Montgomery, Professor
Department of Meteorology
Sponsor: Naval Research Laboratory

OBJECTIVE: The research collaborations will be conducted by Professor Tim Li and Dr. Jiayi Peng at the International Pacific Research Center and the Department of Meteorology of the University of Hawaii. The goal of this work is to investigate the fundamental dynamics and thermal dynamics processes associated with the vortical hot towers (VHTs) on the tropical cyclone (TC) intensification. To obtain a more complete dynamical understanding of the influence of the initial outer-wind structure and Coriolis parameter on the final storm intensity and structure, a series of numerical experiments and diagnostic analyses will be conducted by using the three-dimensional model (MM5). Further diagnosis with the aid of a baroclinic two-layer model will be made to understand the vorticity segregation, merging, and mixing processes associated with the VHTs. This is important for developing a comprehensive link between the VHTs and the intensification of the larger-scale TC vortex. Results of this work will be briefly summarized in a report submitted to the Naval Postgraduate School.

RESEARCH AND DEVELOPMENT OF NEW THEORIES ON HURRICANE INTENSITY AND STRUCTURE CHANGE

Michael T. Montgomery, Professor
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Administration

SUMMARY: This memorandum of understanding (MOU) establishes an agreement between AOML, the Department of Commerce (DoC), and the Naval Postgraduate School (NPS) through which AOML will pay NPS to provide a timeframe through AOML to exchange technical expertise, training, and scientific exchange activities with AIT in areas of mutual interest in the fields of meteorological and oceanographic

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research. This will be accomplished through the detail of Professor Michael Montgomery from NPS to the National Oceanic and Atmospheric Administration.

A THEORETICAL AND OBSERVATIONAL STUDY OF MIDLATITUDE MESOSCALE CONVECTIVE VORTICES IN VERTICAL SHEAR

Michael T. Montgomery, Professor
Department of Meteorology
Sponsor: National Science Foundation

SUMMARY: Because of their longevity and ability to organize convection on the mesoscale (~ 100 km), mesoscale convective vortices (MCVs) have been the focus of studies seeking to improve the prediction of widespread, heavy precipitation events during the warm season. Although progress has been made in the past decade toward identifying conditions favorable for MCV generation, and in linking the strengthening of MCVs to convective regeneration in their vicinity, dynamical processes governing the MCV lifecycle are still not well understood. To better predict potential flooding events in association with MCVs requires a basic understanding of how MCVs form, and what permits them to maintain their coherence in adverse environmental flows.

TRANSPORT, MIXING, AND COHERENT STRUCTURES IN HURRICANE INTENSITY

Michael T. Montgomery, Professor
Department of Meteorology
Sponsor: Naval Research Laboratory

SUMMARY: This is a request for a six-month extension of an existing cooperative agreement (grant N00244-08-1-0022) in order to complete ongoing research support to the National Science Foundation grant entitled "Transport, Mixing, and Coherent Structures in Hurricane Intensity." The contract will focus on quantifying the role of vortical hot towers and vortex Rossby waves in hurricane/typhoon intensification, a major Department of Defense interest in the western Pacific sector.

THE USE OF NASA OBSERVATION AND NUMERICAL MODEL SIMULATIONS TO UNDERSTAND THE HURRICANE "FUEL" AND "ANTI-FUEL" PROBLEMS

Michael T. Montgomery, Professor
Department of Meteorology
Sponsor: NASA Goddard Space Flight Center

SUMMARY: This research is directly relevant to NASA's national objectives to study the earth system for space, develop new space-based and related capabilities, and improve the scientific understanding of a problem of national importance, specifically, the formation and evolution of hurricanes in the Atlantic Ocean basin.

WAVE DYNAMICS IN TROPICAL CYCLONES

Michael T. Montgomery, Professor
Department of Meteorology
Sponsor: National Science Foundation

SUMMARY: This is an "Accomplishment-Based Renewal" of grant #0132006. In accordance with National Science Foundation guidelines dated July 2004 (see NSF 04-23, p. 45) the project description has been replaced with 1) six reprints (uploaded as supplementary documents), 2) a four-page summary, and 3) information on human resources development. Both the summary and the information on human resources have been uploaded in the project description section.

METEOROLOGY

HIGH-IMPACT CYCLONIC DISTURBANCES: DYNAMICS AND PREDICTABILITY

Richard W. Moore, Research Assistant Professor

Department of Meteorology

Sponsor: Naval Postgraduate School

SUMMARY: To better understand the fundamental dynamical processes at work; and to provide insight into how to improve the predictability of high-impact cyclonic storms. The research will focus on two types of disturbances: the diabatic Rossby vortex and tropical cyclones that form from distinct centers.

A MOIST PATHWAY TO EXTRATROPICAL CYCLOGENESIS AND ITS IMPLICATIONS FOR HIGH-IMPACT WEATHER AND ATMOSPHERIC PREDICTABILITY

Richard W. Moore, Research Assistant Professor

Michael T. Montgomery, Professor

Department of Meteorology

Sponsor: National Science Foundation

OBJECTIVE: To advance the knowledge related to diabatically dominated, moist baroclinic cyclones, including an examination of the location and frequency, the inherent physical processes at work, and the forecast model representation and predictability of this type of cyclonic disturbance.

Recent theoretical and observational studies have shown that, in the presence of baroclinicity, a cyclonic vortex can form and intensify via the synergistic interaction of cloud diabatic processes and the flow field associated with the cyclone itself. The resulting disturbance, termed a diabatic Rossby vortex (DRV), has been linked to a wide variety of atmospheric phenomena, all of which can spawn severe weather. It is therefore of great concern that these diabatically dominated disturbances exhibit an alarming lack of predictability. It is the aim of this work to better understand all facets of DRV behavior both in observations and modeling systems, and to explore their role in high-impact weather events.

A National Science Foundation proposal was submitted in July 2008, with co-principal investigators Dr. Moore and Dr. Montgomery. The proposal has been accepted for funding beginning in 2010.

TROPOPAUSE-LEVEL BREAKING WAVES AS PRECURSORS TO TROPICAL CYCLOGENESIS

Richard W. Moore, Research Assistant Professor

Department of Meteorology

Sponsor:

OBJECTIVE: To prepare a global, long-term climatology of tropical transition events, and to investigate the dynamics and predictability of this characteristic type of tropical cyclogenesis.

SUMMARY: A significant fraction of tropical cyclones in the Atlantic basin have extratropical precursors. Of these precursor disturbances, many have a baroclinic origin and exhibit a cold-core structure. For tropical cyclogenesis to occur, therefore, a transformation from a cold to warm-core structure must occur. This process has been termed tropical transition (TT). A number of studies have investigated the TT process in the Atlantic basin, but there remains a need to compile a comprehensive climatology of these events both in and beyond the Atlantic basin.

To build the foundation for a scientific proposal (Dr. Moore as principal investigator), a subjective climatology using model analysis data was completed for the time-period 2002-2008 for the Atlantic, Eastern, and Western Pacific basins. The results indicate that a significant number of these events occur in both the Atlantic and Western Pacific basins. A preliminary study into the predictability of these events using model ensemble data clearly illustrates the difficult nature of the forecast problem: the spread between ensemble members was found to be extremely large, predicting a number of different outcomes for the case in question. These results were presented at the Third THORPEX Scientific Symposium in Monterey, California, September 2009.

METEOROLOGY

AUTOMATION OF OCEAN PRODUCT METRICS

**James Thomas Murphree, Research Associate Professor
Department of Meteorology**

**Sponsor: Program Executive Office Command, Control, Communications,
Computers, and Intelligence**

OBJECTIVE: To develop and apply METOC metrics data collection methods, databases, data analysis, modeling, and metrics computation systems for assessment and improvement of METOC ocean products.

CLIMATE ANALYSIS AND LONG-RANGE FORECASTING

**James Thomas Murphree, Research Associate Professor
Department of Meteorology**

Sponsor: SPAWAR, Naval Meteorology and Oceanography Command

OBJECTIVE: To develop improved analyses and long-range forecasts (lead times of two weeks or longer) of the climate system, especially in areas of Department of Defense interest; and to operationally implement these improvements at Navy METOC support centers.

SUMMARY: This program is a national, collaborative effort involving numerous military and civilian organizations, including the Naval Postgraduate School (NPS) (program lead), the Naval Meteorology and Oceanography Command, the Naval Operational Oceanography Command, the Fleet Numerical Meteorology and Oceanography Center, the Naval Oceanographic Office, Commander Third Fleet, Commander Pacific Fleet, the Air Force Weather Agency, the 14th Weather Squadron, NOAA, and Clear Science, Inc.

In 2009, a number of important advances were made, including the continued development and validation of forecast systems for predicting environmental conditions, and radar and sonar performance, in southwest Asia, East Asia, the North Pacific, North America, and tropical Africa at leads of one week to one year. The principal investigators (PIs) also continued developing and validating a statistical-dynamical system for predicting tropical cyclogenesis in the western North Pacific at leads of one week to six months and a spatial resolution of 2.5 x 2.5 degrees. Thirty-six long-range forecasts in support of global Department of Defense operations were issued and verified, including LRFs requested by C3F, CCSG-11, and NOAC.

PUBLICATIONS:

Meyer, D. and Murphree, T., "Quantifying the Relationship between Large Scale Environmental Factors and Tropical Cyclone Intensities in the Western North Pacific," 2009 (in preparation).

Murphree, T. and Meyer, D., "Global Warming and Tropical Cyclone Activity in the Western North Pacific: Is there a relationship?" 2009 (in preparation).

Murphree, T. and Meyer, D., "Quantifying the Relationship between Large Scale Environmental Factors and Tropical Cyclone Formations in the Western North Pacific," 2009 (in preparation).

Murphree, T., Vorhees, D., and Meyer, D., "Long Range Forecasting of Precipitation and Temperature in Southwest Asia," 2009 (in preparation).

Murphree, T., Meyer, D., Mundhenk, B., and Raynak, C., "Intraseasonal Forecasting of Tropical Cyclogenesis in the Western North Pacific," 2009 (in preparation).

PRESENTATIONS:

Frederickson, P., Murphree, T., Ramsaur, D., Twigg, K., and Barrios, A., "Marine Electromagnetic Climatic Parameters and Smart Climatology," Office of Naval Research FY09 6.2/6.4 Technical Program Reviews, Naval Research Laboratory, Monterey, California, April 2009.

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Meyer, D., Mundhenk, B., and Murphree, T., "Long Range Forecasting of Tropical Cyclone Formations in the Western North Pacific," Tropical Cyclone Conference, Honolulu, Hawaii, April 2009.

Murphree, T., "Advanced Climate Analysis and Long Range Forecasting," 6.2/6.4 METOC Research and Development Project Review Meeting, Oceanographer of the Navy, Washington, D.C., October 2009.

Murphree, T., "Climate Analysis and Long Range Forecasting for the U.S Military," DoD Climate Conference, Asheville, North Carolina, August 2009 (invited).

Murphree, T., "Improving Long Range Support for Naval Operations," Commander Third Fleet Meteorology and Oceanography Conference, San Diego, California, January 2009 (invited).

Murphree, T., "Long Range Ocean Forecasting for ASW," Antisubmarine Warfare Leadership Conference, Naval Meteorology and Oceanography Command, Stennis Space Center, Mississippi, March 2009 (invited).

Murphree, T., "Meteorological and Oceanographic Support of ASW: How Good Is It?" Antisubmarine Warfare Leadership Conference, Naval Meteorology and Oceanography Command, Stennis Space Center, Mississippi, March 2009 (invited).

Murphree, T., Ford, B., Sullivan, D., and Rosenfeld, L., "Analysis of the National Data Buoy Center's Ocean, Technology and Operations Workforce," NOAA/National Data Buoy Center, Stennis Space Center, Mississippi, April 2009 (invited).

Murphree, T., Meyer, D., Mundhenk, B., and Raynak, C., "Statistical-Dynamical Intraseasonal Prediction of Tropical Cyclogenesis in the Western North Pacific, Climate Diagnostics and Prediction Workshop, Monterey, California, October 2009.

CONFERENCES ORGANIZED AND CONDUCTED:

26th Annual Pacific Climate Workshop, an international workshop conducted in collaboration with the U.S. Geological Survey, Pacific Grove, California, 19-22 April 2009.

34th Annual Climate Diagnostics and Prediction Workshop, an international workshop conducted in collaboration with the NOAA Climate Prediction Center, Monterey, California, 26-30 October 2009.

TECHNICAL REPORTS:

Muller, E., Murphree, T., and Jordan, M., "Lightning Launch Commit Criteria Climatology: Climate Analyses and Sensitivity Studies," Naval Postgraduate School Technical Report, 2009.

Murphree, T. and Meyer, D., "Impacts of Global Climate Change on U.S. Air Force Operations: Project Report," Naval Postgraduate School Technical Report, 21 pp., 2009.

THESES DIRECTED:

Crook, J., "Climate Analysis and Long Range Forecasting of Dust Storms in Iraq," Master's Thesis, Naval Postgraduate School, June 2009.

Greeson, J., "Climate Analysis and Long Range Forecasting of Aerosols over Beijing, China," Master's Science Thesis, Naval Postgraduate School, 2009.

Heidt, S., "Long Range Atmosphere-Ocean Forecasting in Support of USW Operations in the Western North Pacific," Master's Thesis, Naval Postgraduate School, September 2009.

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Mundhenk, B., "A Statistical-Dynamical Approach to Intraseasonal Forecasting of Tropical Cyclogenesis in the Western North Pacific," Master's Thesis, Naval Postgraduate School, March 2009.

Ramsaur, D., "Climate Analysis and Long Range Forecasting of Radar Performance in the Western North Pacific," Master's Thesis, Naval Postgraduate School, June 2009.

Raynak, C., "Statistical-Dynamical Forecasting of Tropical Cyclogenesis in the North Atlantic at Intraseasonal Lead Times," Master's Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Climate, Climate Modeling, Climate Prediction, Climate System, Climate Variations, Climatology, Global Climate Change, Global Warming, Military Climatology, Operational Climatology, Smart Climatology, Weather, Medium and Long-Range Forecasting, Atmospheric and Oceanic Variations, Tropical Cyclones, El Niño, La Niña, Madden-Julian Oscillation, Indian Ocean Zonal Mode, North Atlantic Oscillation, Teleconnections, Upper Ocean Temperature, Upper Ocean Currents, Ocean Modeling, Southwest Asia, The Horn of Africa, Korea, Northeast Pacific, Western North America

LIGHTNING LAUNCH COMMIT CRITERIA CLIMATOLOGY

James Thomas Murphree, Research Associate Professor

Department of Meteorology

Sponsor: 45th U.S. Air Force Weather Squadron

OBJECTIVE: To design, develop, and test climatologies of lightning launch commit criteria (LLCC). The climatologies will describe the probability of violating the rules that help mitigate the risk of natural lightning and rocket-induced lightning. The climatologies will have high temporal resolution (e.g., sub-daily to daily) and will span all months. The climatologies will be based on observations and reanalysis data (e.g., from NOAA NARR). The climatologies will support mission planning, development of launch forecasts, and assessment of the LLCCs. Potential collaborators include the NOAA Climate Prediction Center and 14 WS.

METEOROLOGICAL AND OCEANOGRAPHIC METRICS

James Thomas Murphree, Research Associate Professor

Department of Meteorology

**Sponsor: Space and Naval Warfare Systems Command,
Naval Meteorology and Oceanography Command**

OBJECTIVE: This program is composed of a set of projects for which the objective is to develop systems for quantifying and improving the performance and operational impacts of meteorology and oceanography (METOC) support for military operations, including antisubmarine warfare (ASW), mine warfare (MIW), Naval special warfare (NSW), and strike warfare (STW). The data and models from which forecasts are developed, in particular the data and models used at the Naval Oceanographic Office (NAVO), will also be assessed.

SUMMARY: The METOC metrics program is a national, collaborative effort involving numerous military and civilian organizations, including the Naval Postgraduate School (NPS) (program lead), the ASW/MIW Directorate, the Expeditionary Warfare Directorate, the Fleet Operations Directorate, NMOPDC, NAVO, FNMOC, AFWA, Oceanographer of the Navy, the Naval Mine and Antisubmarine Warfare Center, the Naval Strike and Air Warfare Center, the Naval Special Warfare Center, the University of Washington/Applied Physics Lab, Florida State University, NRL, Systems Planning and Analysis, Inc., and Clear Science, Inc.

In 2009, major accomplishments included transitioning to operational use at the Naval Oceanographic Office the metrics systems developed, tested, and validated for monitoring and assessing the performance and operational impacts of METOC support for antisubmarine warfare and Naval special warfare. The development of software for advanced, objective, and quantitative assessments of operational impacts was

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also completed. Reports to NOOC on the overall status of METOC metrics and recommendations for and an outline of an integrated, enterprise-wide metrics program were completed.

PRESENTATIONS:

Murphree, T., "Assessing METOC Support for Naval Special Warfare," Naval Oceanography Special Warfare Conference, Naval Special Warfare Command, Coronado, California, June 2009 (invited).

Murphree, T., "Assessing the Performance and Operational Impacts of Navy Forecasts," Commander Third Fleet Meteorology and Oceanography Conference, San Diego, California, January 2009 (invited).

SOFTWARE AND WEB SITES:

NPS-developed meteorological and oceanographic metrics SIPRNET-based software applications and databases that provide automated, real-time data collection, data analysis, and metrics display. The applications are specific for four different warfare areas --- antisubmarine warfare, Naval special warfare, mine warfare, and strike warfare. These applications are in operational use by:

- Naval Oceanographic Office (NAVO, which hosts the main application and database, the METOC Metrics Web, developed at NPS and transitioned to NAVO in 2009)
- Naval Antisubmarine Warfare Centers, Stennis Space Center and Yokosuka, Japan
- Naval Oceanography Special Warfare Center, San Diego
- Naval Oceanography Mine Warfare Center, Stennis Space Center
- Strike Group Oceanography Team Norfolk and San Diego
- Strike Group Oceanography Detachment Fallon
- METOC Strike Group detachments on all deployed aircraft carriers

KEYWORDS: Operational Assessments, Meteorology, Oceanography, Military Operations, Metrics, Forecast Performance, Operational Impacts, Antisubmarine Warfare, Mine Warfare, Naval Special Warfare, Strike Warfare

METOC METRICS FOR ANTISUBMARINE WARFARE

James Thomas Murphree, Research Associate Professor

Department of Meteorology

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To develop the capability to rapidly map coastal and deep-water seabed geoacoustic properties through characterization of seabed variability.

METOC METRICS FOR NAVAL SPECIAL WARFARE OPERATIONS

James Thomas Murphree, Research Associate Professor

Department of Meteorology

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To develop and apply METOC metrics data collection methods, databases, data analysis, modeling, and metrics computation for METOC support of Naval special warfare operations.

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METRICS FOR MINE WARFARE OPERATIONS

James Thomas Murphree, Research Associate Professor

Department of Meteorology

Sponsor: Naval Oceanographic Office

OBJECTIVE: To operationally implement initial METOC metrics data-collection methods, databases, data analysis, and metrics computation and display systems for METOC support of mine warfare (MIW). To apply systems to collect and analyze METOC and MIW data, assess impacts of METOC products on MIW operations, and develop metrics that quantify the performance and operational impacts of METOC products. To transition a metrics toolset composed of data collections, database, data analysis, and display systems for MIW to the METOC community.

A PERFORMANCE SURFACE BASED ON OPERATIONAL ASSESSMENT OF METOC IMPACT ON SUBMARINE VULNERABILITY TO RADAR DETECTION

James Thomas Murphree, Research Associate Professor

Department of Meteorology

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To develop, apply, and transition to operational use METOC metrics data collection methods, databases, data analysis, modeling, and metrics computation systems for METOC support of antisubmarine warfare operations.

SMART CLIMATOLOGY: OPERATIONAL IMPLEMENTATION

James Thomas Murphree, Research Associate Professor

Department of Meteorology

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To use advanced climate datasets and methods to improve the METOC support provided to warfighters and improve warfighter planning outcomes.

UNDERSTANDING AND PREDICTING CHANGES IN THE WORKFORCE FOR OCEAN SCIENCES, TECHNOLOGY, AND OPERATIONS

James Thomas Murphree, Research Associate Professor

Department of Meteorology

Sponsor: Office of Naval Research/National Oceanographic Partnership Program

OBJECTIVE: To analyze and plan the development of the present state of the workforce that supports the nation's civilian and military ocean science, technology, and operations (OSTO), and to assess the future evolution of this workforce.

SUMMARY: This project is a national, collaborative effort involving numerous civilian and military organizations, including the Naval Postgraduate School, the Scripps Institution of Oceanography, Texas A&M University, Rutgers University, the Marine Advanced Technology Education Center, the Marine Technology Society, the Naval Meteorology and Oceanography Command, the Naval Oceanographic Office, the Naval Meteorology and Oceanography Professional Development Center, the Chief of Naval Operations Strategic Studies Group, the National Oceanographic and Atmospheric Administration, the National Aeronautics and Space Administration, the Minerals Management Service, the Department of Labor, U.S. regional ocean observing systems organizations, and the Consortium for Ocean Leadership.

In 2009, two national workshops on the ocean observing, analysis, and forecasting workforce were conducted. The principal investigators also extended collaborations with federal agencies, research organizations, and industry employers to collect and analyze workforce data. These workforce issues are a high priority for many organizations, for which manpower, readiness, education, and training concerns, especially for its scientific and technical workforce, are a major concern. Work with the Navy included

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analyses of, and a report on, the civilian component of the CNMOC workforce. This report includes the identification of a number of near- and long-term challenges to maintaining the workforce needed to conduct Navy METOC operations, especially the production of sophisticated forecast products from NAVO. This work was conducted in collaboration with Leslie Rosenfeld of the Naval Postgraduate School Department of Oceanography.

PUBLICATION:

Sullivan, D., Murphree, T., and Rosenfeld, L., "An Analysis of the U.S. Ocean Science, Technology and Operations Workforce," 2009 (in preparation).

PRESENTATION:

Murphree, T., Ford, B., Sullivan, D., and Rosenfeld, L., "Analysis of the National Data Buoy Center's Ocean, Technology and Operations Workforce," NOAA/National Data Buoy Center, Stennis Space Center, Mississippi, April 2009 (invited).

CONFERENCES ORGANIZED AND CONDUCTED:

Ocean Instrumentation Technician Workshop, a national workshop addressing critical elements of the ocean observing, analysis, and forecasting workforce, Monterey, California, 19-20 March 2009.

Operational Ocean Forecaster Workshop, a national workshop addressing critical elements of the ocean observing, analysis, and forecasting workforce, Monterey, California, 17-18 September 2009.

TECHNICAL REPORTS:

Murphree, T., Rosenfeld, L. (2007), and Sullivan, D. (2008), "Understanding and Predicting Changes in the Ocean Sciences, Technology, and Operations Workforce," Office of Naval Research, September 2008.

Sullivan, D., Murphree, T., and Rosenfeld, L., "Understanding and Predicting Changes in the Ocean Sciences, Technology, and Operations Workforce," National Oceanographic Partnership Program, November 2008.

KEYWORDS: Ocean Science, Technology, and Operations, Workforce, Navy Workforce, Navy Manpower

NEW TOOLS FOR ESTIMATING AND MANAGING AIR QUALITY IN PRESCRIBED BURNS

Wendell A. Nuss, Associate Chair

Department of Meteorology

Sponsor: Strategic Environment R&D Program

OBJECTIVE: To utilize local high-resolution observations to examine ways to improve numerical modeling of atmospheric processes that effect smoke dispersion in prescribed burns. The Naval Postgraduate School will assist in modeling and data gathering for a field experiment in late 2009.

QUANTIFYING SENSIBLE WEATHER FORECAST VARIABILITY

Wendell A. Nuss, Professor

Department of Meteorology

Sponsor: Office of Naval Research

OBJECTIVE: Sensible weather occurs on small scales, and the development and evolution of these small-scale features depends strongly on the larger scale environment. Synoptic scale variability is represented by the individual members in a well-designed ensemble modeling system. The objective of this research is to

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quantify the local scale variations in sensible weather elements, like fog, due to larger scale variability. The sensitivity of selected weather elements to synoptic scale background variance will be quantified to identify when local scale predictability may be high or low.

SUMMARY: The basic approach used to investigate the tactical-scale sensible-weather forecast sensitivity is to conduct a variety of numerical model experiments. Sensible weather elements are generally not explicitly forecast by numerical models, but will be derived algorithmically using appropriate combinations of explicitly forecast variables. These algorithms are under development and will be applied across a set of ensemble forecasts to determine the ensemble-based probability of occurrence for a particular weather element. Deterministic mesoscale forecasts for the region are available from a 3km resolution forecast from COAMPS and additional COAMPS model runs are being set up using the NCEP ensemble members to initiate COAMPS forecasts to produce a mesoscale ensemble based on the predicted synoptic scale variance.

Work completed in the initial six months of this project consisted of setting up COAMPS for the Monterey Bay region of study, developing the method by which NCEP ensemble forecasts can be used to initialize COAMPS, and examining the algorithms that will be applied to model forecasts to derive sensible weather elements. The COAMPS model was ported to our super-computing cluster to begin this study. NCEP ensemble model fields are being routinely downloaded at the Naval Postgraduate School.

WEATHER FORECASTING FOR FT. ORD PRESCRIBED BURNS

Wendell A. Nuss, Associate Chair
Department of Meteorology
Sponsor: U.S. Army Corps of Engineers

OBJECTIVE: To provide accurate and timely weather forecasts in order to execute the prescribed burn program at Ft. Ord. The Naval Postgraduate School will maintain equipment, web pages, and make daily forecasts to burn personnel to determine optimal burn conditions with minimal smoke impacts.

WEATHER FORECASTING AND SUPPORT FOR FT. ORD BURNS

Wendell A. Nuss, Professor
Department of Meteorology
Sponsor: U.S. Army Corps of Engineers

OBJECTIVE: To provide real-time weather forecasts to conduct prescribed burns at Ft. Ord in order to remove unexploded ordinance. Detailed monitoring of small-scale weather patterns is done using local observations and modeling efforts.

SUMMARY: The project is an ongoing project until all ordinance clean-up is complete at Ft. Ord. During 2009, daily weather forecasts out through five days were done to plan for the execution of prescribed burns during the July to December time-period. Based on forecast weather conditions, two such burns were initiated and successfully completed. Numerical models were run for the area and used to predict smoke dispersion using the CALPUFF model. This was run assuming multiple start times to allow for planning the best time to initiate the burns. Observing sites were maintained and upgraded to meet the focus areas for burning in 2009.

COLLABORATIVE RESEARCH: PHYSICS OF STRATOCUMULUS TOP POST

Qing Wang, Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: To improve the understanding of the physical processes that occur near the stratocumulus top, including wind-shear-induced turbulence.

SUMMARY: In June/July of 2008, extensive aircraft measurements were made of the coast of Monterey Bay using the CIRPAS Twin Otter during the field measurement phase of the Physics of Stratocumulus Top (POST) Experiment. The main efforts in 2009 focused on data analyses. The aircraft slant-path soundings from the Twin Otter were used to study the properties of the interfaces at the top of marine stratocumulus. The observations indicate that, in most cases, a sharp interface layer exists at the top of stratocumulus. The mean differences between heights of turbulent mixing interface and maximum gradient interface are less than 10 m for all flight days, and they are statistically higher than cloud top height with near or more than 20 m for about 30% of all flight days. The geographical distributions of the interfaces are non-uniform. The strong mean wind shear in the vicinity of cloud top is important for formation of separation of above two interfaces from cloud top. The turbulence mixture in the vicinity of cloud top induced by strong mean wind shear could induce variation of vertical distribution of liquid water content and makes it different from normal adiabatic distribution.

PUBLICATION:

Wang, Q., Horner, M.S., Zhou, M., Kalogiros, J.A., Wang, S., and Lenschow, D.H., "Entrainment Zone and the Fine Structure of the Stratocumulus Cloud Top," *Boundary Layer Meteorology*, 2009 (in revision).

PRESENTATION:

Wang, Q., "POST Data Initial Analyses," POST Science and Data Workshop, Salt Lake City, Utah, 5-6 February 2009.

COLLABORATIVE RESEARCH: PHYSICS OF STRATOCUMULUS TOP (POST)

Qing Wang, Associate Chair

Department of Meteorology

Sponsor: National Science Foundation

OBJECTIVE: Stratocumulus clouds (SC) off the west coast of California are studied using a combination of aircraft measurements and modeling. The objective is to improve the understanding of the physical processes that occur near SC top and influence the entrainment process and boundary-layer evolution. The processes include wind shear, entrainment rate, CTEI (cloud-top entrainment instability), solar and infrared radiation, hydrometeor and CCN (cloud condensation nuclei) effects, and the formation and role played by the ELL (entrainment interface layer).

This study is a combination of field measurements and modeling. For the former, the CIRPAS Twin Otter research aircraft is deployed out of Monterey for ~20 flights in SC. It carries a full complement of sensors to produce measurements related to those physical processes. Sensors include the UFT (ultra-fast temperature probe), PVM (fast particulate volume monitor), fast lyman-alpha hygrometer, POI (phased doppler interferometry probe), other droplet probes, gust probe, solar and infrared radiometers, and the standard set of Twin Otter probes producing meteorology and aircraft operating properties. The aircraft is deployed primarily in fields of unbroken SC with a stress on porpoising maneuvers vertically about SC top to detect fine-scale behavior. Boundary layer profiles and near-surface horizontal legs are flown to deduce fluxes. Nexsat and Cloudsat products are compared to aircraft measurements and used to help vector the aircraft to fields of SC. The analysis phase of the field study includes comparisons between the measured physical processes and the calculated cloud-top entrainment velocities with the purpose of clarifying the cause and effect for the latter.

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EVALUATION AND IMPROVEMENT OF HIGH-RESOLUTION MESOSCALE MODELS ON BOUNDARY LAYER SIMULATIONS USING GROUND-BASED OBSERVATIONS

Qing Wang, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: To establish a comprehensive dataset and a set of variable matrix for high-resolution COAMPS evaluation; to investigate new methods for model evaluation, taking into consideration that the model-observation differences are space and time dependent; and to examine issues related to model physics in high-resolution (~km grid spacing) mesoscale models.

SUMMARY: 2009 was the first year of this three-year project. This project involves extensive data handling and analyses and model testing using high-resolution COAMPS. The general approach is to identify model issues through data analyses and model-observation inter-comparison. Improvements of model physics should be a result of these analyses and testing. Eventually, improved model physics will be tested in COAMPS and evaluated against the observations. Within this project, the principal investigators (PIs) will also investigate methods for objective model evaluation, particularly for high-resolution mesoscale models.

The objectives of 2009's work were to obtain data from the relevant agencies, to make initial analyses of the datasets, and to establish COAMPS simulations centered at the measurement sites. The PIs were able to obtain data from 12 measurement towers on Cape Canaveral Air Force Station in 2008. Initial data processing was made on this dataset, including data accessing, consolidation of data collection and site information, and initial data quality checking. The tower-measured meteorological measurements from all 12 towers were analyzed to identify cases for in-depth analyses. The PIs selected a high-wind case associated with Tropical Storm Fay that made a record four landfalls in Florida and was measured at the measurement site. The PIs also set up COAMPS simulations of Tropical Storm Fay before and during its landfalls in Florida using the latest version of operational COAMPS. This initial test simulation revealed the strengths and weakness of the current COAMPS in simulating the tropical storm and will be the basis of model evaluation.

PRESENTATION:

Wang, Q., "Issues on Surface Flux and Boundary Layer Parameterizations," Physical Oceanography Symposium on Recent Progress and Program Overview, Chicago, Illinois, 8-12 June 2009.

IMPROVING SURFACE FLUX PARAMETERIZATION

Qing Wang, Associate Chair
Department of Meteorology
Sponsor: Office of Naval Research

SUMMARY: To continue the on-going joint NRL-NPS CBLAST project, which aims to improve surface layer parameterization in COAMPS and understand air-sea interaction with an emphasis at low wind conditions; it includes two related efforts. One is to use a combination of COAMPS fields and observations to provide physical insight into and development of new parameterizations for the relevant processes; the other is to test and evaluate the new parameterizations and eventually transition the new results into the COAMPS operational/research system. This project is part of the Coupled Boundary Layer Air Sea Transfer (CBLAST) program, whose goal is quantify the fluxes of momentum, heat, and moisture and develop parameterizations which are usable in larger-scale numerical models. The experiment utilized a tower deployed south of Martha's Vineyard in 19 m of water. This tower contained a complete suite of meteorological (in air) and oceanographic (in water) instrumentation aimed at closing the budgets of mass, momentum, and heat.

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SHIPBOARD MEASUREMENTS OF FLUX AND NEAR SURFACE PROFILES AND ANALYSIS OF SURFACE FLUX PARAMETERIZATIONS

Qing Wang, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: To obtain a better understanding of the air-sea-wave interaction and improve surface flux parameterizations involving wave parameters.

SUMMARY: This is the second year of this project as part of the Office of Naval Research Departmental Research Initiative (DRI) named High Resolution Wave-Air-Sea Interaction (HiRes). Naval Postgraduate School (NPS) efforts in this project involve making shipboard measurements of the surface flux and boundary layer profiles over a broad range of wind and wave conditions for the purpose of understanding the wave-affected marine boundary layers and improving surface flux and boundary layer parameterizations for coupled models on various scales. The principal investigators (PIs) analyzed measurements from *R/V Point Sur* in the previous year to evaluate: 1) the performance of the NPS shipboard flux measurement system, and 2) the use of sodar to study the spatial and temporal variation of surface layer wind and thermodynamic properties on a moving platform. Issues of the measurements were identified and improved. In June 2009, the suite of NPS shipboard measurement systems was installed on the *R/V Sprout* to participate in the pilot measurement study of HiRes. The PIs further analyzed this dataset to evaluate the quality of data from all sensors involved and research on possible improvements for the main experiment to be made in June 2010.

At the same, the PIs are continuing the analyses from other datasets to understand the physical processes in air-sea interaction and the performance of the Navy's mesoscale forecast model, COAMPS. These datasets include those from GOTEX and CBLAST.

PRESENTATIONS:

Wang, Q., Lind, R., et al., "NPS Measurements and Analyses for HiRes," HiRes Meeting, La Jolla, California, 5-6 October 2009.

Wang, Q., Konstantinou, N., Garwood, R.W., Wang, S., Hong, X., Rados, K., et al., "Ocean Mixed Layer Response to Gap Wind Scenarios," 16th Conference on Air-Sea Interaction, AMS 89th Annual Meeting, Phoenix, Arizona, 11-15 January 2009.

Wang, Q., Cherrett, R.C., Wang, S.W., Kalogiros, J., Rados, K., Friehe, C.A., and Khelif, D., "Observed and Simulated Temporal and Spatial Variations of Gap Outflow Region," Eighth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, AMS 89th Annual Meeting, Phoenix, Arizona, 11-15 January 2009.

UNDERSTANDING THE AIR-SEA COUPLING PROCESSES IN HIGH-WIND CONDITIONS USING A SYNTHESIZED DATA ANALYSIS/MODELING APPROACH

Qing Wang, Associate Chair
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: To understand the air-sea interaction processes in the coastal region in high-wind conditions; and to improve the boundary layer and surface flux parameterizations for high-resolution mesoscale model (COAMPS), in high-wind conditions.

DEPARTMENT OF METEOROLOGY

**2009
Faculty Publications
and Presentations**

JOURNALS

Anwender, D., Jones, S., Leutbecher, M., and Harr, P., "Sensitivity Experiments for Ensemble Forecasts of the Extratropical Transition of Typhoon Tokage," *Quarterly Journal of the Royal Meteorological Society*, 136, 183-200, 2009.

Elsberry, R.L., Clune, W.M., Elliott, G., and Harr, P.A., "2009a: Evaluations of Global Model Early Track and Formation Predictions during the Combined TCS08 and T-PARC Field Experiment," *Asia-Pacific Journal of Atmospheric Sciences*, 45, 357-373, 2009.

Harr, P.A. and Dea, J.M., "Downstream Development Associated with the Extratropical Transition of Tropical Cyclones over the Western North Pacific," *Monthly Weather Review*, Vol. 137, No. 4, pp.1295-1319, 2009.

Kuo, H.-C., Chang, C.-P., Yang, Y.-T., and Jiang, H.-J., "Western North Pacific Typhoons with Concentric Eyewalls," *Monthly Weather Review*, 137, 3758-3770, 2009.

Westphal, D.L. and Chen, H.-J., "Size-Resolved Forecasting of Volcanic Ash Plumes," *Eos Transactions AGU*, 90(52), Fall Meeting Supplement, Abstract V23F-06, 2009.

CONFERENCE PUBLICATION

Frederickson, P., Guest, P., and Davidson, K., "Atmospheric Performance Surfaces (ATPS)," *Office of Naval Research FY09 6.2/6.4 Technical Program Reviews*, Naval Research Laboratory, Monterey, California, 14-16 April 2009.

PRESENTATIONS

Elsberry, R.L., Montgomery, M.T., Raymond, D., Black, P., Hawkins, J., Harr, P.A., et al., "The Tropical Cyclone Structure-2008 (TCS-08) Program: Objectives on Tropical Cyclone Formation, Intensification, and Structure Change," Third THORPEX Science International Science Symposium, Monterey, California, 14-18 September 2009.

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/TTISS_program_august31.pdf

Frederickson, P., Murphree, T., Ramsaur, D., Twigg, K., and Barrios, A., "Marine Electromagnetic Climatic Parameters and Smart Climatology," Office of Naval Research FY09 6.2/6.4 Technical Program Reviews, Naval Research Laboratory, Monterey, California, April 2009.

Harr, P.A., "The Extratropical Transition of Tropical Cyclones: Downstream Impacts and Predictability," Second Predictability and Dynamics of Weather Systems in the Atlantic-European Sector (PANDOWAE) Workshop, Murnau, Germany, 16-18 February 2009 (keynote invited).

<http://www.pandowae.de/en/newsevents/2nd-workshop>

Harr, P.A., "The THORPEX Pacific Asian Regional Campaign and Affiliated Programs Over the Western North Pacific: Objectives, Strategies, and Accomplishments," First Planning Workshop, THORPEX North Atlantic Waveguide and Downstream Experiment (T-NAWDEX), Edring, Germany, 19-20 February 2009 (invited).

<http://www.pandowae.de/en/newsevents/t-nawdex-workshop>

Harr, P.A., "The THORPEX Pacific Asian Regional Campaign and Affiliated Programs Over the Western North Pacific: Objectives, Strategies, and Accomplishments," International Association of Meteorology and Atmospheric Sciences Assembly, Montreal, Quebec, Canada, 19-29 July 2009 (invited).

<http://www.moca-09.org/e/documents/IAMAS2009Program15w.pdf>

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Harr, P.A., "Typhoon Sinlaku during T-PARC: Sensitivity of Re-Intensification and Downstream Development to the Track Following Recurvature," International Workshop on Advancement of Typhoon Track Forecast Technique, Tokyo, Japan, 30 November-2 December 2009 (invited).

http://www.mri-jma.go.jp/Topics/TyphoonWorkshop_Tokyo_20091130-1202/index.html

Harr, P.A. and Moore, J.M., "The THORPEX Pacific Asian Regional Campaign and Affiliated Programs Over the Western North Pacific: Objectives, Strategies, and Accomplishments," Third THORPEX Science International Science Symposium, Monterey, California, 14-18 September 2009.

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/TTISS_program_august31.pdf

Hawkins, J., Black, P., Harr, P.A., and Elsberry, R.L., "High Altitude Observations Enabling 3-D Pre-Genesis Monitoring," First Tropical Cyclone Structure-2008 Science Workshop, Monterey, California, 29-30 October 2009.

http://www.met.nps.edu/~harr/tcs08/TCS-08_Workshop_agenda_for_web.htm

Meyer, D., Mundhenk, B., and Murphree, T., "Long Range Forecasting of Tropical Cyclone Formations in the Western North Pacific," Tropical Cyclone Conference, Honolulu, Hawaii, April 2009.

Murphree, T., "Advanced Climate Analysis and Long Range Forecasting," 6.2/6.4 METOC Research and Development Project Review Meeting, Oceanographer of the Navy, Washington, D.C., October 2009.

Murphree, T., "Assessing METOC Support for Naval Special Warfare," Naval Oceanography Special Warfare Conference, Naval Special Warfare Command, Coronado, California, June 2009 (invited).

Murphree, T., "Assessing the Performance and Operational Impacts of Navy Forecasts," Commander Third Fleet Meteorology and Oceanography Conference, San Diego, California, January 2009 (invited).

Murphree, T., "Climate Analysis and Long Range Forecasting for the U.S Military," DoD Climate Conference, Asheville, North Carolina, August 2009 (invited).

Murphree, T., "Improving Long Range Support for Naval Operations," Commander Third Fleet Meteorology and Oceanography Conference, San Diego, California, January 2009 (invited).

Murphree, T., "Long Range Ocean Forecasting for ASW," Antisubmarine Warfare Leadership Conference, Naval Meteorology and Oceanography Command, Stennis Space Center, Mississippi, March 2009 (invited).

Murphree, T., "Meteorological and Oceanographic Support of ASW: How Good Is It?" Antisubmarine Warfare Leadership Conference, Naval Meteorology and Oceanography Command, Stennis Space Center, Mississippi, March 2009 (invited).

Murphree, T., Ford, B., Sullivan, D., and Rosenfeld, L., "Analysis of the National Data Buoy Center's Ocean, Technology, and Operations Workforce," NOAA/National Data Buoy Center, Stennis Space Center, Mississippi, April 2009 (invited).

Murphree, T., Meyer, D., Mundhenk, B., and Raynak, C., "Statistical-Dynamical Intraseasonal Prediction of Tropical Cyclogenesis in the Western North Pacific," Climate Diagnostics and Prediction Workshop, Monterey, California, October 2009.

Sanabia, E. and Harr, P.A., "The Impact of Typhoon Sinlaku on the Northern Hemisphere Midlatitudes during T-PARC," Third THORPEX Science International Science Symposium, Monterey, California, 14-18 September 2009.

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/TTISS_program_august31.pdf

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Sanabia, E.R. and Harr, P.A., "Re-Intensification of TY Sinlaku Prior to Extratropical Transition," First Tropical Cyclone Structure-2008 Science Workshop, Monterey, California, 29-30 October 2009.
http://www.met.nps.edu/~harr/tcs08/TCS-08_Workshop_agenda_for_web.htm

Wang, Q., "Issues on Surface Flux and Boundary Layer Parameterizations," Physical Oceanography Symposium on Recent Progress and Program Overview, Chicago, Illinois, 8-12 June 2009.

Wang, Q., "POST Data Initial Analyses," POST Science and Data Workshop, Salt Lake City, Utah, 5-6 February 2009.

Wang, Q., Lind, R., et al., "NPS Measurements and Analyses for HiRes," HiRes Meeting, La Jolla, California, 5-6 October 2009.

Wang, Q., Konstantinou, N., Garwood, R.W., Wang, S., Hong, X., Rados, K., et al., "Ocean Mixed Layer Response to Gap Wind Scenarios," 16th Conference on Air-Sea Interaction, AMS 89th Annual Meeting, Phoenix, Arizona, 11-15 January 2009.

Wang, Q., Cherrett, R.C., Wang, S.W., Kalogiros, J., Rados, K., Friehe, C.A., and Khelif, D., "Observed and Simulated Temporal and Spatial Variations of Gap Outflow Region," Eighth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, AMS 89th Annual Meeting, Phoenix, Arizona, 11-15 January 2009.

WHITE PAPER

Davidson, K.L., Frederickson, P.A., and Huynh, T.V., "NPS System-of-Systems Exploitation of Knowledge of Atmospheric and Ocean Surface Impacts for MIO and Maritime Security," White Paper prepared for NORTHCOM, Commander Navy Meteorology and Oceanography Command, 9 pp., February 2009.

TECHNICAL REPORTS

Guest, P.S., "CBE09-4 Quick Look Report," Naval Postgraduate School, Monterey, California, 2008.

Guest, P.S., "CBE/TNT09-3 Quick Look Report," Naval Postgraduate School, Monterey, California, 2009.

Guest, P.S., "CBE10-1 Quick Look Report," Naval Postgraduate School, Monterey, California, 2008.

Guest, P.S., "TNT09-2 Quick Look Report," Naval Postgraduate School, Monterey, California, 2009.

Muller, E., Murphree, T., and Jordan, M., "Lightning Launch Commit Criteria Climatology: Climate Analyses and Sensitivity Studies," Naval Postgraduate School Technical Report, 2009.

Murphree, T. and Meyer, D., "Impacts of Global Climate Change on U.S. Air Force Operations: Project Report," Naval Postgraduate School Technical Report, 21 pp., 2009.

Murphree, T., Rosenfeld, L. (2007), and Sullivan, D. (2008), "Understanding and Predicting Changes in the Ocean Sciences, Technology, and Operations Workforce," Office of Naval Research, September 2008.

Sullivan, D., Murphree, T., and Rosenfeld, L., "Understanding and Predicting Changes in the Ocean Sciences, Technology, and Operations Workforce," National Oceanographic Partnership Program, November 2008.

**DEPARTMENT OF
OCEANOGRAPHY**

**JEFFREY D. PADUAN
CHAIR**

OCEANOGRAPHY

OVERVIEW:

The Department of Oceanography has developed a broad research program focused on physical oceanography to meet the anticipated future needs of the Navy. Our basic research themes are the development of scientific capabilities to measure, analyze, and forecast fields of littoral ocean variables, which occur in association with synoptic/mesoscale processes over limited, regional, temporal domains.

The areas of emphasis include coastal and nearshore ocean dynamics, air-sea interaction phenomena, and boundary currents. Regions of interest include the polar seas, coastal ocean regions, and strategic straits of the world. Our applied research themes are the application of analyses and forecasts of upper ocean synoptic/mesoscale variability to Naval operations. Areas of emphasis include the impact of littoral processes, eddies, and boundary currents on ocean surveillance systems, the effect of storms on acoustic propagation and ambient noise, and the impact that the wave climate exerts on nearshore processes and beach character as it pertains to mine/mine-countermeasure and amphibious warfare.

These research themes require the development of numerical, ocean-prediction models and synoptic observation capabilities. They are achieved through the employment of modern dynamical and mathematical principles, numerical and statistical methods, computational and graphical facilities, and in-site and remote-sensing observations.

CURRICULA SERVED:

- Meteorology and Oceanography
- Operational Oceanography
- Oceanography
- Undersea Warfare

DEGREES GRANTED:

- Master of Science in Meteorology and Physical Oceanography
- Master of Science in Physical Oceanography
- Doctor of Philosophy in Physical Oceanography

RESEARCH THRUSTS:

- Acoustical Oceanography
- Air-Sea Interaction and Ocean Turbulence
- Coastal/Littoral/Nearshore Oceanography
- Numerical Prediction and Data Assimilation
- GI&S and Navigation
- Polar Oceanography

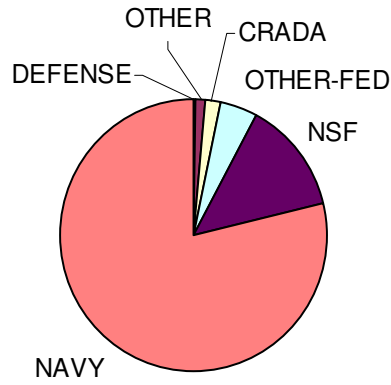
RESEARCH FACILITIES:

- Rapid Environmental Assessment Laboratory
- Ocean Acoustic Observatory at Point Sur
- Computer Graphics Laboratory
- Monterey Inner Shelf Observatory
- Moored Equipment Laboratory
- Calibration Laboratory
- Tactical Environmental Support Laboratory
- Interactive Digital Environmental Analysis

OCEANOGRAPHY

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Oceanography is provided below:



Size of Program: \$7.2M

OCEANOGRAPHY

Jeffrey D. Paduan
Professor and Chair
831-656-3350
paduan@nps.edu

Mary L. Batteen
Professor
831-656-3265
batteen@nps.edu

Thomas H.C. Herbers
Professor
831-656-2917
thherber@nps.edu

Albert J. Semtner
Professor Emeritus
831-656-3267
sbert@nps.edu

Robert H. Bourke
Professor Emeritus
831-656-2962
rbourke@nps.edu

James H. MacMahan
Assistant Professor
831-656-2379
jhmacmah@nps.edu

William Shaw
Research Assistant Professor
831-656-3270
wjshaw@nps.edu

Ching-Sang Chiu
Professor
831-656-3239
chiu@nps.edu

Timour Radko
Associate Professor
831-656-3318
tradko@nps.edu

Rebecca E. Stone
CDR, USN, Military Faculty
Program Officer for METOC
831-656-3269
restone@nps.edu

Peter C. Chu
Professor
831-656-3688
pcchu@nps.edu

Timothy P. Stanton
Research Associate Professor
and Research Associate Chair
831-656-3144
stanton@nps.edu

Vicki Taber
LCDR, USN
Military Faculty
Lecturer
831-656-7712
vltaber@nps.edu

Curtis A. Collins
Professor
831-656-3271
collins@nps.edu

Wieslaw Maslowski
Research Professor
831-656-3162
maslowsk@nps.edu

Edward Thornton
Distinguished Professor
Emeritus
831-656-2847
thornton@nps.edu

John A. Colosi
Professor
831-656-3260
jacolosi@nps.edu

Steven R. Ramp
Visiting Research Professor
831-656-2201
sramp@nps.edu

Robin T. Tokmakian
Research Associate Professor
831-656-3255
rtt@nps.edu

Roland W. Garwood
Professor Emeritus
831-656-2673
garwood@nps.edu

D. Benjamin Reeder
CDR, USN, Military Faculty
Assistant Professor
831-656-3268
dbreeder@nps.edu

Arlene Guest
Senior Lecturer
831-656-2226
aguest@nps.edu

Leslie Rosenfeld
Research Associate Professor
831-656-3253
lkrosenf@nps.edu

Eugene C. Haderlie
Distinguished Professor
Emeritus
831-656-2918
haderlie@nps.edu

AN ANALYSIS OF SOUTH CHINA SEA SHELF AND BASIN ACOUSTIC TRANSMISSION DATA

Ching-Sang Chiu, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To complete the analysis of both the shelf and basin acoustic transmission data collected from the Northeastern South China Sea (NE SCS) during the Windy Island Soliton Experiment (WISE). These data were collected between April 2005 and October 2006.

The objectives of the NE SCS shelf acoustic data analysis are twofold: the first is to compare and contrast, in terms of phenomenology and statistics, the sound intensity fluctuations resulting from a transmitted acoustic pulse through nonlinear depression internal waves, nonlinear elevation internal waves, and/or a mix of both types of waves. The second is to develop and validate a modified theory which expands upon previously established theories of the statistics of sound intensity fluctuations by incorporating critical signal parameters and channel characteristics, including signal and channel bandwidths, multipath arrival times (separations), and additional bottom-induced variance, all of which control the number of independent intensities/arrivals in the received signal.

The primary objective of the basin acoustic data analysis is to study and characterize the supertidal-to-seasonal-scale impacts of the transbasin nonlinear internal waves on long-range transmission loss. A secondary objective is to understand the variability of the observed ambient noise level in the basin and quantify what portion, if any, of this variability is related to the nonlinear internal wave activities/climatology.

SUMMARY: The focus in 2009 was the analysis of the basin acoustic data. The receiver data was processed to yield the arrival structure and its temporal changes over the nine-month period. The observed temporal variability in the arrival structure and in the acoustic intensity was analyzed using time-series techniques with emphasis to elucidate the connection to the observed sound speed variability induced by the mesoscale ocean variability and the nonlinear transbasin internal tides and waves. From a pure observational perspective, key findings were reported in the 157th and 158th Meetings of the Acoustical Society of America. Initial model and model-data comparison results were reported in a referee journal article that has been accepted and is in press.

PUBLICATION:

Bernotavicius, C.S., Chiu, C.-S., Miller, C.W., Reeder, D.B., Wei, R.-C., Yang, Y.-J., and Chiu, L., "Modeling a 400-Hz Signal Transmission through the South China Sea Basin," *Journal of Computational Acoustics* (accepted and in press).

PRESENTATIONS:

Chiu, C.-S., "Observation and Modeling of Acoustic Signal Intensity Fluctuations in the Northeastern South China Sea Shallow Waters," 2nd International Conference on Shallow Water Acoustics, Shanghai, China, 16-20 September 2009 (invited).

Chiu, C.-S., "Temporal Variability of Acoustic Signal Transmitted through the South China Sea Basin," ONR Physical Oceanography Program Review Symposium, Chicago, Illinois, 7-13 June 2009.

Chiu, C.-S., "A View of 6.1 Shallow Water Acoustics Research – Past, Present, and Future," ONR Shallow Water Acoustics 20 Years Roadmap Steering Group Workshop, Arlington, Virginia, 7-8 October 2009.

Chiu, C.-S., Miller, C.W., Reeder, D.B., Reeves, J.M., and Ramp, S.R., "Observed Temporal Statistics of Acoustic Travel Time and Intensity in the South China Sea," 157th Meeting of the Acoustical Society of America, Portland, Oregon, 18-22 May 2009 (invited).

Chiu, C.-S., Miller, C.W., Wei, R.-C., Chen, C.-F., Chiu, L., and Wei, R.-C., "Observation and Modeling of Sound Propagation through a Dynamic Ocean on the Continental Shelf of the Northeastern South China Sea," 158th Meeting of the Acoustical Society of America, San Antonio, Texas, 26-30 October 2009.

THESIS DIRECTED:

Bernotavicius, C.S., "Modeling a 400-Hz Signal Transmission through the South China Sea Basin," Master's Thesis, Naval Postgraduate School, March 2009.

KEYWORDS: Littoral Acoustics, Shelfbreak, Nonlinear Internal Waves

**CMG COLLABORATIVE RESEARCH: A SYSTEMATIC APPROACH TO LARGE
AMPLITUDE, INTERNAL WAVE DYNAMICS: AN INTEGRATED
MATHEMATICAL/OBSERVATIONAL/REMOTE SENSING MODEL**

Ching-Sang Chiu, Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: To develop an effective and accurate theoretical model to investigate the generation, propagation, and transformation of large-amplitude, internal solitary waves over variable bottom topography; and then to integrate the resulting internal wave model with an improved radar-imaging model for remote sensing of the surface signatures of these strongly nonlinear internal waves.

**DETERMINATION OF THE DETECTION AND CLASSIFICATION PROBABILITIES AND
RANGE LIMITS OF INEXPENSIVE ACOUSTIC SENSORS AND DATA PROCESSING
TECHNIQUES FOR MONITORING ODONTOCETI WHALES**

Ching-Sang Chiu, Professor

Curtis Allan Collins, Professor

John E. Joseph, Research Associate

Department of Oceanography

Sponsor: Chief of Naval Operations, N45

OBJECTIVE: To support Navy anti-submarine-warfare training activities at SCORE (San Clemente Island) by mitigating the effects of mid-range sonar on marine mammals. The approach has been to evaluate and predict the performance of inexpensive passive systems for monitoring vocalizing *Odontoceti* whales using conditional statistical measures. These performance measures include detection and classification probabilities and range limit against false-alarm rate. FY09 activities included developing methods to detect and classify marine mammal vocalizations, recording data from an array of bottom-mounted hydrophones in the San Nicholas Basin, determining the spatial and temporal variability of marine mammal vocalizations in the San Nicholas Basin, and understanding the physical characteristics of the basin that govern the propagation of acoustic energy and affect the behavior of marine mammals. The long-range goal of these studies is to measure the response of marine mammals to acoustic energy that is introduced to the marine environment by anthropogenic means.

SUMMARY: Major accomplishments included continued data collection activities and coordination of N45 research activities at West Coast universities and NOAA Laboratories. The Naval Postgraduate School's (NPS) FY09 data-collection activities included maintaining an autonomous acoustic recorder on Sur Ridge, environmental moorings near SIO HARP packages which bracket either side of the SCORE range in the San Nicholas Basin, collection of data from SCORE hydrophones, collection of environmental data on SIO/UCSD acoustic moorings in southern California and off the Washington coast, and collection of AIS data along the central California coast. Support was also provided for NUWC tests of the M3R system at the SCORE range in July 2009. SCORE data collected by NPS are being stored at the Department of Defense's (DoD) Major Shared Resource Center at the Stennis Space Center.

An initial attempt to develop a detector for *Ziphius cavirostris* vocalizations was completed. This involved compiling one-hundred *Ziphius cavirostris* vocalizations from acoustic data recorded at two High-frequency Acoustic Recording Package (HARP) locations: the NPS Point Sur HARP and the Scripps Institution of Oceanography's (SIO) site H HARP. This ensemble was analyzed via a principal component analysis (PCA). The results of the PCA verified the statistical robustness of the signal and yielded one dominant mode which accounted for 73% of the variance. The dominant mode was used to create a kernel for a matched filter detection scheme. The subsequent detector output was statistically evaluated against a ground truth. The ground truth identified 28,434 *Ziphius* clicks by visually inspecting over 170 minutes of data recorded by NPS' Data Acquisition System (DAS) at the Southern California Offshore Range (SCORE). The inability to visually discriminate a signal embedded in noise created a conservatively biased, ground-truth estimate which increased the detector's false alarm rate. At an acceptable 0.1% false alarm rate, the detector had an overall 44% probability of detection. A further assessment of the detector's performance divided the data into two categories: cluttered and uncluttered. At a false alarm rate of 0.1%, the probability of detection was 26% and 61% respectively.

The goal of the current effort is to validate and improve this detector. This effort is using HARP data collected by UCSD at site H in the San Nicholas Basin for a period in June 2008 when recordings from adjacent SCORE hydrophones are available. The improved detector will be then used with both HARP and SCORE data to identify *Ziphius cavirostris* vocalizations. The vocalization detections will in turn yield data about click trains, patterns, and eventually, individual behavior. The detector should also be able to be integrated into the M3R system at SCORE.

In FY09 the HARP mooring off Pt. Sur was moved from the SOSUS site to Sur Ridge so as to better monitor coastal whale migrations and ambient noise associated with coastal vessel transits. The purpose of this mooring is to provide information on marine mammal migrations into and out of the Navy training ranges to the north (Quinault and Gulf of Alaska) and south (SCORE). In CY09, the recording cycle for the mooring was increased from 5 minutes every 20 minutes to 5 minutes every 10 or 15 minutes. The performance of the HARP was also upgraded by incorporation of the newly designed SIO hydrophone.

The AIS receiver installed at Pt. Sur continued successful data collection in FY09. These data are being used by UCSD for graduate student research on the impact of merchant vessel traffic on marine mammal population. They will also be useful for studies of ambient acoustic noise recordings on Sur Ridge.

Environmental moorings near SIO HARP packages which bracket either side of the SCORE range in the San Nicholas Basin were redeployed. These moorings provided information on local water conditions and measured the upper ocean transport across the San Nicholas Basin. Analysis of a subset of these data near Eel Point, San Clemente Island, was completed (Armijo, 2008). Support was also provided for NUWC tests of the M3R system at the SCORE range in July 2009, including participation by student/officers on the *R/V New Horizon*. Marine mammal data collection activities during this period have been provided to both Cascadia and PACFLT. Environmental data collected during the cruise are currently being analyzed by students; a strong ocean front along Tanner Bank was observed. Data recordings at SCORE hydrophones were collected by NPS through March 2009. These data are being stored at the DoD's Major Shared Resource Center at the Stennis Space Center. Data collection activities on the old array will continue until the new array becomes operational.

Coordination and funding of N45 efforts continued in FY09, using both grants and contracts. In addition to replicating FY08 activities, three additional efforts were supported: 1) a marine mammal survey in a Gulf of Alaska Navy Training Range on NOAA Ship *Oscar Dyson* in May, 2) an August/September study of marine mammal response to sound in the Mediterranean, and 3) summer PACFLT marine mammal studies in SOCAL and Hawaii. Progress reports for N45-funded activities that have been published and distributed by NPS and listed as "Technical Reports" are listed below.

PRESENTATION:

Oleson, E.M., Soldevilla, M.S., Calambokidis, J., Collins, C., Wiggins, S.M., and Hildebrand, J., "Distribution Patterns of Delphinids in the California Current Ecosystem Observed through Acoustic Monitoring of Species-Specific Echolocation Clicks," Acoustics '08 Paris, Paris, France, 24 June-4 July 2008.

TECHNICAL REPORTS:

Hildebrand, J., "Marine Mammal Acoustic Monitoring and Habitat Investigation, Southern California Offshore Region," Naval Postgraduate School Technical Report, NPS-OC-09-006, 57 pp., June 2009.

Ketten, D.R. and Mountain, D.C., "Beaked and Baleen Whale Hearing: Modeling Responses to Underwater Noise," Naval Postgraduate School Technical Report, NPS-OC-09-005, 25 pp., June 2009.

Mellinger, D., "Datasets of Odontocete Sounds Annotated for Developing Automatic Detection Methods," Naval Postgraduate School Technical Report, NPS-OC-09-008, 22 pp., July 2009.

Oleson, E.M., Calambokidis, J., Falcone, E., Schorr, G., and Hildebrand, J.A., "Acoustic and Visual Monitoring for Cetaceans along the outer Washington coast," Naval Postgraduate School Technical Report, NPS-OC-09-001, 35 pp., March 2009.

Rone, B.K., Douglas, A.B., Clapham, P., Martinez, A., Morse, L.J., and Calambokidis, J., "Cruise Report for the April 2009 Gulf of Alaska Line Transect Survey (GOALS) in the Navy Training Exercise Area," Naval Postgraduate School Technical Report, NPS-OC-09-007, 31 pp., June 2009.

Stafford, K.M., "Monitoring Cetaceans in the North Pacific in the North Pacific," Naval Postgraduate School Technical Report, NPS-OC-09-003, 10 pp., April 2009.

KEYWORDS: Odontocetes, Underwater Acoustics, Sonobuoys, Hydrophones

QUANTIFYING, PREDICTING, AND EXPLOITING UNCERTAINTY RESEARCH INITIATIVE MANAGEMENT

Ching-Sang Chiu, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Professor Chiu will serve as a Program Officer for the Ocean Acoustics Program of the Office of Naval Research. Professor Chiu will utilize his substantial background and knowledge of ocean acoustics and of the Navy community to provide expert technical and management support. The major duties of the assignment will be: 1) to plan, organize, direct, and coordinate the Quantifying, Predicting, and Exploiting Uncertainty (QPE) Department Research Initiative (DRI) for the Ocean Acoustics Research Program (321 OA) and Code 32; 2) to enhance interaction among the various investigators in basic and applied research in the QPE DRI by holding workshops and attending relevant meetings to identify needs and highlight opportunities for the DRI; and 3) to fiscally manage the QPE DRI research projects, including determining the allocation of resources and providing the necessary documentation justification and procurement materials.

AN ANALYSIS OF GTSP/ARGO/MOODS DATA USING THE OPTIMAL SPECTRAL DECOMPOSITION METHOD

Peter C. Chu, Professor
Department of Oceanography
Sponsor: National Oceanic and Atmospheric Administration/NODC

OBJECTIVE: To produce monthly mean temperature and salinity fields from observational data provided by the National Ocean Data Center using the Optimal Spectral Decomposition Method. Temporally varying sound-speed profiles can be computed from these temperature and salinity fields. This will greatly enhance the capability of the Navy's anti-submarine warfare, mine warfare, and special operations.

This project is a joint effort between researchers at the Naval Postgraduate School (NPS) and NOAA/NODC. The project will enhance the optimal spectral decomposition (OSD) method to process temperature (T) and salinity (S) data from the NODC's Global Temperature-Salinity Profile Program

(GTSP) datasets; develop a strategy to extract ocean profiles from the Navy's Master Oceanographic Data Set (but not in the GTSP database) and incorporate with the profiles from GTSP in the OSD calculation for producing the monthly gridded T-S fields; and provide monthly 3D (T, S) field for rapid climate change studies.

PUBLICATIONS:

Chu, P.C., 2009: Observational studies on association between eastward equatorial jet and Indian Ocean dipole. *Journal of Oceanography*, in press.

Chu, P.C., 2009: Statistical characteristics of the global surface current speeds obtained from satellite altimeter and scatterometer data. *IEEE Journal of Selected Topics in Earth Observations and Remote Sensing*, **2** (1), 27-32.

Chu, P.C., and C.W. Fan, 2009: A conserved minimal adjustment scheme for stabilization of hydrographic profiles. *Journal of Atmospheric and Oceanic Technology*, in press.

Chu, P.C., and C.W. Fan, 2009: Transformed flux-form semi-Lagrangian scheme. *Terrestrial, Atmospheric, and Oceanic Sciences*, in press.

Chu, P.C., and Y.-H. Kuo, 2009: Nutrient pumping/advection by propagating Rossby waves in the Kuroshio Extension. *Deep-Sea Research II*, in press.

Galanis, G., G. Emmanouil, P.C. Chu, and G. Kallos, 2009: A new methodology for the extension of the impact of data assimilation on ocean wave prediction. *Ocean Dynamics*, **59**, 523-535.

CONFERENCE PUBLICATIONS:

Chu, P.C., 2009: Analysis of remotely sensed ocean data by the optimal spectral decomposition (OSD) method. *IEEE/MTS OCEANS 2009*, 8 pages in CD-Rom.

Chu, P.C., 2009: Weibull distribution for global surface current speeds obtained from satellite altimetry. *Sixteenth Conference on Satellite Meteorology and Oceanography*, American Meteorological Society, 8 pages.

Chu, P.C. and Y.-H. Kuo, 2009: Biophysical variability in the Kuroshio Extension from Altimeter and SeaWiFS. *IEEE/MTS OCEANS 2009*, 8 pages in CD-Rom.

Chu, P.C., C. Sun, and C.-W. Fan, 2009: Detection of thermohaline structure and meridional overturning circulation above and below the ocean surface. *Twenty First Conference on Climate Variability and Change*, American Meteorological Society, 8 pages.

PRESENTATIONS:

Invited

Chu, P.C., "Argo – Opportunities and Challenges," Asia Oceania Geophysical Society, Singapore, 11-16 August 2009 (invited).

Chu, P.C., "Generation of False Static Instability in Ocean (T, S) Data Assimilation," Asia Oceania Geophysical Society, Singapore, 11-16 August 2009 (invited).

Contributed

Chu, P.C., "Analysis of Remotely Sensed Ocean Data by the Optimal Spectral Decomposition (OSD) Method," *IEEE/MTS OCEANS 2009*, Biloxi, Mississippi, 26-29 October 2009.

Chu, P.C., “Existing of False Static Instability in Ocean (T, S) Data Assimilation,” International Association of Physical Sciences of Oceans, Montreal, Canada, 20-24 July 2009.

Chu, P.C. and Fan, C.-W., “Transformed Flux-Form Semi-Lagrangian Schemes for Coastal Ocean Modeling,” Eighth Conference on Coastal Atmospheric and Oceanic Prediction and Process, American Meteorological Society, Phoenix, Arizona, 11-15 January 2009.

Chu, P.C. and Hsieh, C.P., “Multifractal Thermal Structure in the Western Philippine Sea Upper Layer,” American Geophysical Union Joint Assembly, Toronto, Canada, 24-27 May 2009.

Chu, P.C. and Kuo, Y.-H., “Biophysical Variability in the Kuroshio Extension from Altimeter and SeaWiFS,” IEEE/MTS OCEANS 2009, Biloxi, Mississippi, 26-29 October 2009.

Chu, P.C., Ivanov, L., and Fan, C.W., “Optimal Spectral Decomposition (OSD) for Observational Ocean Data Analysis,” Thirteenth Symposium on Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, American Meteorological Society, Phoenix, Arizona, 11-15 January 2009.

Chu, P.C., Sun, C., and Fan, C.-W., “Detection of Thermohaline Structure and Meridional Overturning Circulation Above and Below the Ocean Surface,” Twenty First Conference on Climate Variability and Change, American Meteorological Society, Phoenix, Arizona, 11-15 January 2009.

Chu, P.C., Sun, C., and Fan, C.W., “Observations of Meridional Overturning Circulation Above and Below the Ocean Surface,” American Geophysical Union Fall Meeting, San Francisco, California, 14-18 December 2009.

Chu, P.C., Ivanov, L.M., Melnichenko, O.V., and Wells, N.C., “Rossby Wave Propagation in the Tropical North Atlantic Observed from Argo Floats,” International Association of Physical Sciences of Oceans, Montreal, Canada, 20-24 July 2009.

CONTRIBUTION TO BOOK:

Chu, P.C., 2009: First passage time analysis for climate prediction. In: *Stochastic Physics and Climate Modeling*, edited by T.N. Palmer and P. Williams, Chapter 6, Cambridge University Press (ISBN-13:9780521761055).

KEYWORDS: Ocean Optimal Spectral Decomposition, OSD, GTSP, First Passage Time for Model Predictability

LITTORAL OCEANOGRAPHY FOR MINE WARFARE

Peter C. Chu, Professor
Department of Oceanography
Sponsor: Naval Oceanographic Office

OBJECTIVE: To enhance the U.S. Navy’s mine warfare (MIW) capabilities through analysis of the Navy’s littoral oceanographic and MIW routing datasets.

The goal of this program is to develop an analysis tool for analyzing oceanographic data with application to the MIW effort on 1) determination of periodicity for MIW route surveys, including influences by natural forcing functions (storms, clima, etc.) and human activity (i.e., clutter increased by shipping activity, etc.); and 2) development of analogous CONUS areas that are environmentally “analogous” to a potential operational area of interest. These CONUS sites would then be usable for more rigorous operational training and evaluation.

PUBLICATIONS:

Chu, P.C., 2009: Mine impact burial prediction from one to three dimensions. *Applied Mechanics Reviews*, ASME, **62**, 010802.

Chu, P.C., 2009: Statistical characteristics of the global surface current speeds obtained from satellite altimeter and scatterometer data. *IEEE Journal of Selected Topics in Earth Observations and Remote Sensing*, **2** (1), 27-32.

Chu, P.C., and C.W. Fan, 2009: A conserved minimal adjustment scheme for stabilization of hydrographic profiles. *Journal of Atmospheric and Oceanic Technology* (in press).

Chu, P.C., and C.W. Fan, 2009: Transformed flux-form semi-Lagrangian scheme. *Terrestrial, Atmospheric, and Oceanic Sciences*, in press.

Chu, P.C., and R.-F. Li, 2009: Topical and geographical focus of Chinese oceanographic research – A study of trends in publication. *Bulletin of the American Meteorological Society*, **90**, 1442-1450.

Chu, P.C., C.W. Fan, and P.R. Gefken, 2009: Diagnostic-photographic determination of drag/lift/torque coefficients of high speed rigid body in water column. *Journal of Applied Mechanics*, in press.

Galanis, G., G. Emmanouil, P.C. Chu, and G. Kallos, 2009: A new methodology for the extension of the impact of data assimilation on ocean wave prediction. *Ocean Dynamics*, **59**, 523-535.

PRESENTATIONS:

Chu, P.C., Almquist, J.B., Gefken, P., and Watson, K., “Underwater Bomb Trajectory Prediction for Stand-Off Assault Breaching Weapon Fuse Improvement (SOABWFI),” European Undersea Defense Technology – Europe, Carnes, France, 9-11 June 2009.

Chu, P.C., Kyriakidis, K., Haeger, S.D., and Ward, M., “Tidal Effect on Chemical Spill in San Diego Bay,” International Conference on Coastal Management, Malta, 14-16 September 2009.

THESES DIRECTED:

Coke, H., “Route Survey Periodicity for Mine Warfare,” Master’s Thesis, Naval Postgraduate School, September 2009 (unclassified with secret appendix). (Selected for the NUWC Division Newport Award for Excellence in Undersea Warfare.).

Garstka, J.P., “Optimizing U.S. Navy Mine Warfare and Department of Homeland Security Maritime Security Requirements: A Quantitative Analysis of Bottom Sediments to Determine Analogous Areas in the Strait of Hormuz and Continental United States,” Master’s Thesis, Naval Postgraduate School, September 2009 (nominated for the NUWC Award and the NSWC Award).

Wheatley, N., “Determining Route Survey Periodicity for Mine Warfare: Investigation of Bedforms, Waves, Tides, and Currents,” Master’s Thesis, Naval Postgraduate School, September 2009.

KEYWORDS: Littoral Oceanography for Mine Warfare, Mine Impact Burial Prediction, Mine Detection

RED-TEAMING IMPROVISED, EXPLOSIVE-DEVICE ATTACKS IN SHALLOW WATER

Peter C. Chu, Professor

Department of Oceanography

Sponsor: Joint Improvised Explosive Device Defeat Organization Research Program

OBJECTIVE: To develop a model that can be incorporated into the Red teaming/wargaming of the consequences of terrorist employment of underwater, improvised-explosive devices (IEDs) within surf zones, rivers, and fords. It will also allow Red teaming of the ability to mitigate the effects of this employment tactic by employment of JADM and required target location to be successful.

This program will develop a six-degrees-of-freedom (DOF) computational bomb-maneuvering model to accurately predict the trajectory pattern, velocity, and orientation of the warheads when they are released from any of the various dispense concepts. This model development provides a tool to accurately determine the underwater bomb-trajectory path so that the final detonation position relative to the IED position can be predicted.

PUBLICATIONS:

Chu, P.C., 2009: Mine impact burial prediction from one to three dimensions. *Applied Mechanics Reviews*, ASME, **62**, 010802.

Chu, P.C., C.W. Fan, and P.R. Gefken, 2009: Diagnostic-photographic determination of drag/lift/torque coefficients of high speed rigid body in water column. *Journal of Applied Mechanics*, in press.

CONFERENCE PUBLICATION:

Chu, P.C., 2009: Development of 6-DOF model for underwater bomb trajectory prediction with application to the stand-off assault breaching weapon fuse improvement (SOABWFI). *European Undersea Defense Technology 2009 Conference*, 10 pp. (DVD-Rom).

PRESENTATION:

Chu, P.C., Almquist, J.B., Gefken, P., and Watson, K., "Underwater Bomb Trajectory Prediction for Stand-Off Assault Breaching Weapon Fuse Improvement (SOABWFI)," European Undersea Defense Technology – Europe, Carnes, France, 9-11 June 2009.

THESIS DIRECTED:

Bushnell, J., "Tail Separation and Density Effects on the Underwater Trajectory of the JDAM," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: 3D Underwater Bomb Trajectory Prediction, Tail Separation, STRIKE35 Model, JABS, JDAM

THE WAVE EFFECT ON UNDERWATER BOMB TRAJECTORY AND TAIL SEPARATION

Peter C. Chu, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: To investigate the wave effect on underwater bomb trajectory and tail separation. The proposed work will include: 1) development of a new version of the Naval Postgraduate School (NPS) 6-DOF model with the capability to predict the bomb maneuvering in the water column due to sloping surface, 2) analysis on the underwater bomb trajectory and orientation due to wave propagation, and 3) determination of the wave effect on the tail separation.

This program will develop a module to include the bomb impact on the sloping ocean surface. The new version of the 6-DOF model will have the ability to predict bomb maneuvering in the water column due to

the sloping surface with wave effects; and will develop a drag/lift module for each specific bomb configuration. The best form of the module is to construct semi-empirical formulae for drag/lift coefficients which depend on Reynolds number and attack angle. For the Office of Naval Research-scheduled full-size, inert-weapon trajectory experiment (NAWC-China Lake), the impact-points at the surface (0 ft) and bottom (40 ft) will be measured. The plan is to determine the accuracy of the NPS 6 DOF model by comparing the measured and predicted impact points.

PUBLICATIONS:

Chu, P.C., 2009: Mine impact burial prediction from one to three dimensions. *Applied Mechanics Reviews*, ASME, **62**, 010802.

Chu, P.C., and R.-F. Li, 2009: Topical and geographical focus of Chinese oceanographic research – A study of trends in publication. *Bulletin of the American Meteorological Society*, **90**, 1442-1450.

Chu, P.C., C.W. Fan, and P.R. Gefken, 2009: Diagnostic-photographic determination of drag/lift/torque coefficients of high speed rigid body in water column. *Journal of Applied Mechanics*, in press.

Galanis, G., G. Emmanouil, P.C. Chu, and G. Kallos, 2009: A new methodology for the extension of the impact of data assimilation on ocean wave prediction. *Ocean Dynamics*, **59**, 523-535.

CONFERENCE PUBLICATION:

Chu, P.C., 2009: Development of 6-DOF model for underwater bomb trajectory prediction with application to the stand-off assault breaching weapon fuse improvement (SOABWFI). *European Undersea Defense Technology 2009 Conference*, 10 pp. in DVD-Rom.

PRESENTATION:

Chu, P.C., Almquist, J.B., Gefken, P., and Watson, K., “Underwater Bomb Trajectory Prediction for Stand-Off Assault Breaching Weapon Fuse Improvement (SOABWFI),” *European Undersea Defense Technology – Europe*, Carnes, France, 9-11 June 2009.

THESIS DIRECTED:

Bushnell, J.M., “Tail Separation and Density Effects on the Underwater Trajectory of the JDAM,” Master’s Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: 3D Underwater Bomb Trajectory Prediction, Tail Separation, Wave Effect, STRIKE35 Model, JABS, JDAM

CHARACTERIZATION AND CLASSIFICATION OF MARINE MAMMAL VOCALIZATION

Curtis Allan Collins, Professor
Department of Oceanography
Sponsor: Chief of Naval Operations, N45G

OBJECTIVE: To coordinate the in-water portion of a test of hydrophones located on the Navy’s SCORE range for passive detection of beaked and other whales at and near the Navy training facility. The Naval Postgraduate School will work with the Naval Undersea Warfare Center, Scripps, and Cascadia Research.

COLLABORATIVE RESEARCH: ESTIMATION OF OCEAN CURRENTS AND WAVE-EDDY TURBULENCE FROM FLOAT OBSERVATIONS

Curtis Allan Collins, Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To derive methods for the practical analysis of Lagrangian float observations from boundary current regions using advanced mathematical methods. This was a collaborative project with Dr. Leonid Piterbarg and Dr. Leonid Ivanov of the Mathematics Department of the University of Southern California.

SUMMARY: An innovative technique for the analysis of Lagrangian data was developed and applied to Argo subsurface float data in the North Atlantic and RAFOS float data in the California Current System. A non-traditional parametric approach involving exit-time concepts (from non-equilibrium statistical mechanics) and small sample statistics (based upon probability weighted moments) was used in these studies. This allowed utilization of shorter observation series than traditional non-parametric methods. A model of across-shore transport of RAFOS floats off central California was developed.

A double spectral approach was developed to separate different types of motions that contributed to float drift. Specifically, mean currents were separated from structured (wave-eddy) turbulence and appropriate decomposition was developed for mesoscale currents off central California. Monte-Carlo methods were used to examine possible biases and errors of the technique. Results improved the understanding of slope and shelf exchange off central California.

PUBLICATIONS:

Ivanov, L.M., C.A. Collins, and T.M. Margolina, 2009: System of quasi-zonal jets off California extracted from satellite altimetry. *Geophysical Research Letters*, 36, L03609, doi:10.1029/2008GL036327.

Ivanov, L.M., C.A. Collins, P. Marchesiello, and T.M. Margolina, 2009: On model validation for meso/submesoscale currents: Metrics and application to ROMS off central California. *Ocean Modeling*, 28, 209-225.

Piterbarg, L.I., 2009: A simple method for computing velocities from tracer observations and model output. *Applied Mathematical Modeling*, doi:10.1016/j.apm.2008.12.006.

CONTRIBUTION TO BOOK:

Ivanov, L.M., C.A. Collins, 2009: Modal decomposition of oceanic circulation: Applications for high-resolution models and Lagrangian data, In: *Ocean Circulation and El Niño: New Research*, edited by J.A. Long and D.S. Wells, Chapter 2, Nova Science Publishers, Inc., New York.

KEYWORDS: California Current, Lagrangian Measurements, Isentropic Analysis, Mesoscale Eddies

THE EFFECTS OF EDDIES AND WAVES ON WESTWARD TRANSPORT OFF CENTRAL CALIFORNIA

Curtis Allan Collins, Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To understand the role of mesoscale variability and Rossby waves in the observed westward transport (WT) of the California Current System (CCS). In situ observations, remote-sensed observations, and numerical modeling are used to Nowcast mesoscale eddy variability in the CCS off central California and to quantify associated WT. The goal is to understand how eddies, jets, and waves, as well as their interactions, affect WT; and to determine the scales responsible for this process.

Parameterization schemes for WT will also be developed in a form sufficiently simplified to be verified from sparse observations and to permit biological and climate applications. This is a collaborative study with Dr. Leonid Ivanov of Moss Landing Marine Laboratories.

SUMMARY: Satellite altimetry and float data were used to understand propagation of annual and semi-annual Rossby waves off California, as well as the associated westward transport. Data indicated that in the region off central California, Rossby waves were present most of the time. Different propagation regimes were identified using propagation speed, wave steepness (a measure of wave nonlinearity), and degree of spatial coherence. The waves typically evolved as weakly nonlinear waves with a recurrence time of about 105-120 (195-210) days for the semiannual (annual) component. When wave amplitudes reached maximum possible values (the saturation stage), the spatial coherence of the wave field decreased considerably, and wave packets and separated features (interpreted as mesoscale eddies) were clearly observed. Propagation speed also decreased with the degree of nonlinearity of the wave field, and westward propagation (zero mean propagation speed) stopped in the saturation stage.

PUBLICATION:

Ivanov, L.M., C.A. Collins, T.M. Margolina, and V.N. Eremeev, Rossby wave propagation and westward transport off California. *Geophysical Research Letters*, submitted.

CONFERENCE PRESENTATIONS:

Collins, C.A., Ivanov, L., Margolina, T., and Melnichenko, O., "Reconstruction of Ocean State from Noisy and Gappy Data: An Approach and Practical Applications," Ocean Sciences Meeting, Portland, Oregon, 22-26 February 2010.

Ivanov, L., Collins, C.A., and Margolina, T., "The Impact of Mesoscale Processes on Westward Transport off Central California," IAMAS-IAPSO-IACS Joint Assembly, Montreal, Canada, 19-29 July 2009.

Ivanov, L., Collins, C.A., and Margolina, T., "Weakly Nonlinear Rossby Waves, Quasi-Zonal Jets and Westward Transport off California," Ocean Sciences Meeting, Portland, Oregon, 22-26 February 2010.

KEYWORDS: California Current, Lagrangian Measurements, Rossby Waves, Mesoscale Eddies

ESTIMATION OF OCEAN CURRENTS AND WAVE-EDDY TURBULENCE FROM FLOAT OBSERVATIONS

**Curtis Allan Collins, Professor
Department of Oceanography
Sponsor: National Science Foundation**

OBJECTIVE: To develop new mathematical techniques for understanding the physics of ocean circulation from float observations.

OCEANOGRAPHIC CONDITIONS OFF CENTRAL CALIFORNIA

**Curtis Allan Collins, Professor
Department of Oceanography
Sponsor: National Marine Fisheries Service, NOAA**

OBJECTIVE: To monitor the state of the California Current off central California using quarterly research cruises.

SUMMARY: Regional hydrographic surveys were conducted in June and October 2008 and January 2009. Results showed the position of the California Current varying from 200 km from the coast in June 2008 to 300 km in October 2008 and January 2009. In October, the offshore edge of the California Current was

about 100 km farther from the coast than in January. This was indicated by the strong gradient of westward-increasing dynamic height observed at the three offshore stations on Line 67 to the west-southwest of Monterey Bay. The subarctic character of these waters was also indicated by salinity <33 at 10 m, temperature >15°C at 10 m at the station farthest from shore, and vessel-mounted ADCP measurements (not shown) which indicated 0.5 m/s south-southwest flow.

Although upwelling-favorable gale-force winds occurred in June, the ocean response seemed to be confined to shallower coastal waters. Despite these strong winds, waters in the upper 50 m remained stratified. High concentrations of Chl *a* in coastal waters confirmed the limited extent of the upwelling response to the strong winds. Below 300 m and within 100 km of the coast, isopycnals sloped downward toward the coast, indicating poleward flow of the California Undercurrent over the continental slope.

Coastal time series measurements indicated that in late winter and spring 2008, maximum upwelling-favorable wind stress occurred about 1.5 months earlier than usual, resulting in a corresponding seasonal acceleration for coastal sea surface temperatures, salinities, nitrate, Chl *a*, and primary productivity. This seasonal response was superimposed upon the continuing cool phase of the Pacific Decadal Oscillation, resulting in continued large positive anomalies of nitrate, Chl *a*, and primary productivity. Coastal conditions returned to normal in late summer and fall 2008.

A principle forcing of central California waters is offshore Ekman transport of ocean waters caused by alongshore wind stress. The magnitude of the 2008 springtime wind forcing was the same as that of the long-term mean; but the maximum occurred in mid-April, about a month and a half earlier than usual. This month and a half lead in the offshore transport cycle continued through August, resulting in less offshore transport in the summer than normal. Offshore Ekman transport during fall was about 50 tonnes/s, larger than normal, and the minimum, in February 2009, occurred about a month later than normal. In March and April 2009, offshore transport was almost the same as the long-term mean.

Within Monterey Bay, the coolest temperatures in the past 20 years were observed in June 2008, and primary production continued at high levels in 2008, as documented by a positive seasonal Chl *a* anomaly of about 1 mg m⁻³. Sightings of the jumbo squid, *Dosidicus gigas*, by remotely-operated vehicles continued during this cool phase in 2008 at the rate of about 500 per year versus zero prior to 1998. Finally, pCO₂ (pH) levels were ~450 ppm (8), accelerating upward (downward) trends observed in the previous 15 years.

Surface temperatures during late winter and spring in Monterey Bay were about 1.5°C cooler than the average, but subsequently approached normal values. Surface salinities peaked a month and a half sooner than normal in June, and during the spring months were about 0.4 greater than normal. As with temperature, salinity approached normal values during the late summer and fall. Surface nitrate values were more than twice their normal values from January through July, with a broad maximum of 13 µM from mid-April through mid-June. Similarly, primary production values were largest in May, almost 400 mg m⁻³, more than twice the mean value. The maximum primary production occurred about a month and a half earlier than usual. Finally, Chl *a* too followed the pattern of salinity, nitrate, and primary production, with the largest values in May, about 6 mg m⁻³, about 2 mg m⁻³ larger than the average May value and about a month and a half earlier than the normal maximum.

PUBLICATION:

McClatchie, S., Goericke, R., Schwing, F.B., Bograd, S.J., Peterson, W.T., Emmett, R., et al., "The State of the California Current, Spring 2008-2009: Cold Conditions Drive Regional Differences," *CalCOFI Reports*, 50, 44-68, 2009.

CONFERENCE PUBLICATION:

Castillo Trujillo, A.C., Castro Valdez, R., Collins, C., and Mascarenhas, A., "Estudio de La Capa de Mezcla Frente a la Peninsula de Baja California y la Entrada del Golfo de California," *Geos.*, 29 (1), pg. 86, Mexican Oceanography Conference, Puerto Vallarta, November 2009.

PRESENTATIONS:

Bograd, S.J., Castro, C.G., Chavez, F., Collins, C.A., Combes, V., DiLorenzo, E., and Ohman, M.D., "The California Undercurrent, 1949-2008," Ocean Sciences Meeting, Portland, Oregon, 22-26 February 2010.

Collins, C.A., Margolina, T.M., and Collins, C.A., "Effects of Sampling Resolution on Geostrophic Transport Estimates for CalCOFI Line 67," CalCOFI Conference, Pacific Grove, California, 7-9 December 2009.

Zamora, U.D., Collins, C.A., and Margolina, T.M., "Direct Measurements of Deep Flow in the California Current System," Fall National Meeting, American Geophysical Union, San Francisco, California, 14-18 December 2009.

TECHNICAL REPORTS:

Rago, T.A., Michisaki, R., Marinovic, B., Blum, M., and Whitaker, K., "Physical, Nutrient, and Biological Measurements of Coastal Waters off Central California in October 2008," Naval Postgraduate School Technical Report, NPS-OC-09-004, 73 pp., May 2009.

Rago, T.A., Michisaki, R., Marinovic, B., Blum, M., and Whitaker, K., "Physical, Nutrient, and Biological Measurements of Coastal Waters off Central California in January 2009," Naval Postgraduate School Technical Report, NPS-OC-09-009, 46 pp., November 2009.

THESIS DIRECTED:

Zamora, U., "Atlas of Deep Current Observations for Central California," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: California Current System, Coastal Circulation, Central California

SHIPBOARD STUDIES OF THE CALIFORNIA CURRENT SYSTEM OFF CENTRAL CALIFORNIA

Curtis Allan Collins, Professor
Department of Oceanography
Sponsor: University of California-Santa Cruz

OBJECTIVE: Modern shipboard measurement systems will be used to sample the California Current System off central California. Cruises are proposed for fall 2008 and summer 2009.

ANALYSIS AND MODELING OF OCEAN ACOUSTIC FLUCTUATIONS AND MOORED OBSERVATIONS OF THE PHILIPPINE SEA SOUND-SPEED STRUCTURE

John A. Colosi, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: In the interest of improving ocean acoustic modeling and prediction capability, this study seeks to establish the connections between oceanographic sound-speed variability and observed acoustic fluctuations from both deep- and shallow-water environments. The basic science of this proposal is well aligned with the interests of the Navy and the Department of Defense, as undersea acoustic surveillance and remote sensing rely critically on a clear knowledge of the oceanographic sound-propagation environment and on a firm understanding of the appropriate acoustic propagation physics given a particular environment.

SUMMARY: This project started in October 2008. The main efforts to date have been the preparation and execution of the spring 2009 Philippine Sea Pilot Study and the preparation for the 2010-2011 year-long study. During the year, seven papers on various oceanographic and acoustics topics were published.

PUBLICATIONS:

Cole, S.T., D.L. Rudnick, and J.A. Colosi, "Seasonal evolution of the upper ocean horizontal structure and the remnant mixed layer," *J. Geophys. Res.*, 2009 (in press).

Colosi, J.A., and A.K. Morozov, "Statistics of normal mode amplitudes in an ocean with random sound speed perturbations: Cross mode coherence and mean intensity," *J. Acoust. Soc. Am.*, 126(3), pp. 1026-1035, 2009.

Colosi, J.A., J. Xu, M.A. Dzieciuch, P. Worcester, B. Howe, J. Mercer, and B. Spindel, "Temporal and vertical scales of acoustic fluctuations from 75-Hz, broadband transmissions to 87-km range in the eastern North Pacific Ocean," 126(3), pp. 1069-1083, 2009.

Grigorieva, N.S., J.A. Mercer, R.K. Andrew, M.A. Wolfson, B.M. Howe, and J.A. Colosi, "The interference component of the acoustic field corresponding to the Long-Range Ocean Acoustic Propagation Experiment," *J. Acoust. Soc. Am.*, 125(4), pp. 1919-1929, 2009.

Mercer, J., J. Colosi, B. Howe, M. Dzieciuch, R. Stephen, and P. Worcester, "LOAPEX: The Long-Range Acoustic Propagation Experiment," *IEEE J. Oceanic Eng.*, 34(1), pp. 1-11, 2009.

Stephen, R., M. Dzieciuch, P. Worcester, R. Andrew, B. Howe, J. Mercer, and J. Colosi, "Deep shadow zone arrivals on the seafloor," *J. Acoust. Soc. Am.*, 126(2), pp. 599-606, 2009.

Van Uffelen, L.J., P.F. Worcester, M.A. Dzieciuch, D. Rudnick, and J.A. Colosi, "Effects of upper ocean sound speed structure on deep acoustic shadow zone arrivals at 500- and 1000-km range," *J. Acoust. Soc. Am.*, 2009 (in press).

PRESENTATIONS:

Acoustical Society of America Meetings, San Antonio and Portland, 2009.

International conference on underwater acoustic measurements: Technologies and results, Napflion, Greece, June 2009.

North Pacific Acoustic Laboratory Meeting, September 2009.

THESES DIRECTED:

Blodget, P., "Laser Propagation through the Irregular Ocean Surface," Master's Thesis, Naval Postgraduate School, September 2009.

Cornell, J., "Simulation and Theory for 3-D Acoustic Propagation through Nonlinear Shallow Water Internal Waves," Master's Thesis, Naval Postgraduate School, June 2009.

Thompson, S., "Sound Propagation Considerations for a Deep-Ocean Acoustic Network," Master's Thesis, Naval Postgraduate School, December 2009.

OCEANOGRAPHY

AN ANALYSIS OF OCEANOGRAPHIC AND ACOUSTIC FLUCTUATIONS FOR DEEP- AND SHALLOW-WATER ENVIRONMENTS: TOWARDS A UNIFICATION OF OBSERVATIONS, MODELS, AND THEORY

John A. Colosi, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To establish the connections between oceanographic sound-speed variability and observed acoustic fluctuations from both deep- and shallow-water environments. The basic science of the proposal is well aligned with the interests of the Navy and the Department of Defense, as undersea acoustic surveillance and remote sensing rely critically on a clear knowledge of the oceanographic sound-propagation environment and on a firm understanding of the appropriate acoustic propagation physics given a particular environment.

THE 2009 NORTH PACIFIC ACOUSTIC LABORATORY WORKSHOP

John A. Colosi, Professor
Department of Oceanography
Sponsor: Various

OBJECTIVE: To host the Office of Naval Research (ONR) 2009 North Pacific Acoustic Laboratory (NPAL) Workshop at the La Playa Hotel in Carmel, August 30 through September 3. Since 1999, ONR has sponsored the NPAL workshops as a means to coordinate research activities and carry out program review for the 30-40 principle investigators involved in deep-water ocean acoustics. The workshop will be funded by participant registrations fees of approximately \$500.00, and individuals will be responsible for their own transportation and lodging.

THE EVOLUTION OF OCEANIC SURFACE WAVES ACROSS A MUDDY CONTINENTAL SHELF

Thomas H.C. Herbers, Associate Chairman
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Funds are provided for Dr. Herbers, who will collaborate with O'Reilly at the Scripps Institute of Oceanography, to deploy wave sensors across the muddy Louisiana continental shelf during the waves-seafloor interaction MURI experiments. The resulting wave measurements will be used to develop, refine, and test new models for wave dissipation mechanisms induced by the presence of mud at the seafloor.

THE EVOLUTION OF OCEAN SURFACE WAVES ACROSS A MUDDY CONTINENTAL SHELF

Thomas H.C. Herbers, Associate Chair
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To understand and predict the effects of a muddy seafloor on the transformation of ocean waves across a continental shelf. Future Naval applications of this work include remote sensing of seafloor properties to reduce uncertainties in planning for mine-countermeasures, anti-submarine warfare, and expeditionary warfare in denied areas.

OCEANOGRAPHY

IN SITU WAVE OBSERVATION IN THE OFFICE OF NAVAL RESEARCH HIGH-RESOLUTION AIR-SEA INTERACTION DEPARTMENTAL RESEARCH INITIATIVE

Thomas H.C. Herbers, Associate Chair
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To participate in the Office of Naval Research High-Resolution Air-Sea Interaction Departmental Research Initiative. The objective is to advance observational and modeling techniques for monitoring the sea state around a vessel. The field experiment will be conducted off Point Conception, California, using the floating platform FLIP with a suite of meteorological and oceanographic instruments, airborne and ship-board radar systems, and an array of moored buoys. This research will describe the in situ wave measurement component using GPS-based surface-following buoys.

WAVE ATTENUATION BY BOTTOM FRICTION ON THE CONTINENTAL SHELF

Thomas H.C. Herbers, Associate Chair
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To understand and predict the effects of sea floor morphology on the transformation of ocean waves across a continental shelf. Future Naval applications of the work include remote sensing of seafloor properties to reduce uncertainties in planning for mine-countermeasures, anti-submarine warfare, and expeditionary warfare in denied areas.

AUTONOMOUS WIDE APERTURE CLUSTER FOR SURVEILLANCE

John E. Joseph, Research Associate
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To build and test components and algorithms for an Autonomous Wide Aperture Cluster for Surveillance (AWACS) of quiet targets operating in complex, littoral, shallow-water environments. Specific technical objectives are: to explore the limits and capabilities of the REMUS towed and hull-mounted array systems to autonomously detect, classify, and localize quiet targets; to evaluate current and develop new methods and capabilities of adaptive environmental and adaptive acoustical sampling, search and data assimilation techniques, including new, adaptive data-gathering schemes for optimal physical-acoustical-geoacoustical estimations; to develop mobile sources for in situ TL measurements and for DCL testing; to explore the limits of signal processing, with emphasis on dynamic array control using a cluster of REMUS vehicles for adaptive DCI of quiet targets, based on improving probability-of-detection and reducing the false alarm rate; and to explore and develop vehicle command and control methods based on adaptive environmental and acoustics sensing, and on models of vehicle and cluster behavior.

AUTONOMOUS WIDE APERTURE CLUSTER FOR SURVEILLANCE

John E. Joseph, Research Associate
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Seapower 21, the Chief of Naval Operation's vision for the 21st century Navy, emphasizes antisubmarine warfare (ASW) as a high-priority Naval capability. This represents a shift in priority and requires the calculus of ASW to be significantly changed from the present platform-based approach, using submarines and surface ships, to a distributed networked force utilizing rapid detect-to-engage capabilities. At issue is the surveillance of very quiet diesel-electric (DE) submarines operating electrically in the littoral shallow waters (SW) in and around strategic ports. The SW environment is very noisy due to local shipping, and its sound propagation is highly variable in both time and space. Consequently, the performance of current ASW assets with passive sonar systems is unacceptable. The tactical ranges

required for efficient operation specify a signal-to-noise ratio that is presently unobtainable. Furthermore, the present number of false alarms from local ships prohibits effective fire-control solutions. Thus, the detection, classification, and localization (DCL) of DE submarines requires a new concept-of-operation based on new systems and technologies.

AUTONOMOUS WIDE APERTURE CLUSTER FOR SURVEILLANCE

John E. Joseph, Research Associate

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: Autonomous Wide Aperture Cluster for Surveillance (AWACS) is a multi-disciplined team effort comprised of a number of collaborating academic and scientific institutions, Fleet operation support communities, and manufacturers of ocean sensors and platforms. The long-term objective of the AWACS Program is to develop an undersea surveillance system consisting of a cluster of autonomous vehicles for use in complex, littoral, shallow-water environments. The vehicles will be capable of sampling oceanographic, bottom, and acoustic features in a local environment and, as a networked cluster, will collectively feed adaptive sampling and search algorithms, leading to improved detection, classification, and localization (DCL) of quiet targets.

The Naval Postgraduate School (NPS) contribution is focused on development, implementation, and validation of a quasi-real-time environment, transmission and ambient noise estimation system that assimilates data retrieved by the cluster of vehicles to recursively improve estimates of ocean, bottom and acoustic parameters with reduced error variances in the volume of interest, thereby improving probability of detection while reducing false alarm rates.

SUMMARY: This multi-year program is based on an extensive build-test-build approach in which AWACS components and algorithms are designed, built, tested, and evaluated; then redesigned and rebuilt based on test results. The NPS effort in 2009 built upon the previous year's effort to produce an improved estimation system incorporating noise estimation algorithms that are capable of providing near-real-time support with sufficient spatial and temporal resolution for a surveillance system consisting of a cluster of mobile assets. Use of parallelization computing methods has greatly improved acoustic processing time. This is being incorporated into noise prediction algorithms.

NPS established a small network along the central California coast using commercial, off-the-shelf receivers to begin analysis of ambient noise variability with shipping traffic over a moored hydrophone off Pt. Sur. These reports are also fed to the Department of Transportation MSSIS system, which provides much wider area AIS coverage. The MSSIS reports have been archived for 2009 and will help establish shipping statistics in support of noise prediction in various regions of interest.

KEYWORDS: Littoral, Acoustics, Surveillance, Autonomous Underwater Vehicle, Anti-Submarine Warfare, Ambient Noise

DEVELOPMENT OF A REAL-TIME SIGNAL-TO-NOISE RATIO ESTIMATION SYSTEM (FOR PLUS INP)

John E. Joseph, Research Associate

Ching-Sang Chiu, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: A persistent surveillance system can adjust to changing acoustic environments to improve overall performance by adapting search and sampling schemes such that the system is always optimizing probability of detection (PD), while minimizing the probability of false alarm (PFA). In challenging environments, signals from quiet targets can easily be masked by ambient noise (AN). Adaptation of search and sampling schemes should strive to maximize the directional signal-to-noise ratio (SNR) within the context of other operational constraints to be effective. The primary objective of this effort is to build and test a near-real-time SNR estimation system that supports a persistent surveillance system consisting of

mobile sensors operating in a challenging ocean environment. The output of the system will be 3D fields of SNR estimates that can be used to develop a cost function for an optimization algorithm to provide guidance to mission planners and operators in making adaptive search and sampling decisions and fed to a surveillance system to optimize system performance. The specific technical objectives are:

- To develop methods and algorithms for extracting ambient noise information from available resources at a mission control site for assimilation into an ambient noise estimation system. Resources may include (but are not limited to) satellite information, commercial shipping traffic data, meteorological data, information returned through the AUV surveillance network, and other sources, including intelligence information.
- To develop algorithms for assimilating directional ambient noise data into a 3D gridded field providing a depiction of the current ambient noise environment in a small shelf-break region.
- To develop algorithms that can derive 3D directional SNR fields for scenarios that consider a potential target with expected acoustic characteristics and distribution density being detected with a passive receiver array operated over a range of bearings in a surveillance region of interest.
- To build scalability into the system to cover larger areas with sufficient resolution to support persistent surveillance operation in real time.
- To provide measures of uncertainty associated with ambient noise and SNR estimates based on the age, location, and source of assimilated data (including climatology).

SUMMARY: This effort is one component of a much larger and more comprehensive program known as the Persistent Littoral Undersea Surveillance Innovative Naval Prototype (PLUS INP). PLUS INP is a multi-year multi-agency project involving research efforts at several educational institutions, Navy laboratories, and small businesses. PLUS INP uses an integrated team approach, which has resulted in various levels of collaboration in this project.

The NPS effort in 2009 focused on extending the work done under the AWACS Program and developing methods for accurate directional noise predictions. Comparisons of AIS data collected at NPS with the Navy's historical shipping database show there are areas with large differences in the "expected versus actual" shipping density, which would result in significant differences in shipping noise prediction. Analysis is ongoing to determine accurate methods for including AIS data and data from other methods of ship tracking into a noise prediction system.

NPS participated in the Kauai-09 field test, providing near-real-time support for the 10-day test, in conjunction with other EA and Optimization Team members. During the sea test, the teams demonstrated end-to-end support from data collection/assimilation from field assets, ocean modeling, acoustic modeling, system performance prediction, and optimized system lay-down recommendations to mission planners (C2).

KEYWORDS: Littoral, Acoustics, Surveillance, Autonomous Underwater Vehicle, Anti-Submarine Warfare, Ambient Noise

DRIFTER TRAJECTORIES IN RIVERINE ENVIRONMENTS

James H. MacMahan, Assistant Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: To field evaluate the QinetiQ North America river drifters in a number of natural rivers. QinetiQ North America will provide two river drifters that measure river bottom, position, and temperature. In addition to the deployment of QinetiQ river drifters, 20 Naval Postgraduate School GPS-equipped river drifters will be deployed to evaluate the drifter trajectories. Various deployment schemes will be performed to determine spatial coverage and determine the number of drifters influenced by river dead zones. Researchers plan to perform deployments in the Sacramento River, California; Kootenai River, Idaho; and Elkhorn Slough, Monterey Bay, California. A database of drifter behavior will be obtained and shared amongst other riverine programs sponsored by the Office of Naval Research Coastal Geosciences.

OCEANOGRAPHY

DURIP: SHALLOW-WATER AUTONOMOUS VEHICLES

James H. MacMahan, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To augment Office of Naval Research-sponsored core programs and DRI field efforts focused on obtaining in situ observations on macrotidal flat, riverine, and ocean environments through unique autonomous vehicles. Two instrumentation requests are proposed: 1) the purchase of a YSI EcoMapper autonomous underwater vehicle, and 2) the purchase of an instrumentation suite for a PI-owned SeaRobotics autonomous surface catamaran system. In addition to the research focus of this request, the autonomous systems, particularly the EcoMapper, will be integrated into Naval Postgraduate School classroom exercises, providing hands-on opportunities for Naval officer students to use these instruments and analyze the data. Naval students will also use this equipment for their thesis projects.

LINKING THE SURF ZONE AND THE INNER SHELF: CROSS TRANSPORT MECHANISMS

James H. MacMahan, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To collaboratively examine the cross-shore exchange between the surfzone and the inner shelf on a natural sandy beach with persistent rip currents. The proposed work includes a four-week-long field experiment located at Sand City, Monterey Bay, California, to be held in spring 2009. Repetitive-cluster drifter deployments are planned to measure the Lagrangian mean velocities and dispersion of the rip current jet outside of the surfzone. In addition, high-resolution ADCP velocity measurements will be used to observe the vertical structure and temporal fluctuations of the Eulerian circulation flow field from 2 m water depth to 13 m water depth, thus spanning the transition from the surf zone to the inner shelf. The observations will be evaluated with a well-established, Navy-used, nearshore numerical model, Delft3D, in full-3D mode, including wave-current interaction and wave group forcing. The proposed technical approach, including Lagrangian (drifters), Eulerian (ADCPs), and numerical tools, allows, for the first time, an evaluation of the cross-shore exchange between the surfzone and the inner shelf on a rip-change.

MACROTIDAL POSITION-TRACKING DRIFTER AND AUTONOMOUS CATAMARAN FIELD OBSERVATIONS

James H. MacMahan, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To provide new in situ observations of hydrodynamics in an estuarine/tidal-flat system through inexpensive position-tracking drifters and unique, autonomous surveying platforms. A primary objective is to obtain synoptic maps of velocities within the tidal flat for various tidal levels. In addition, drifter-derived dispersion and diffusivity will be estimated at various morphodynamic regions in the macrotidal environment. This study will be integrated into concurrent observational programs of the tidal flat system and parallel process and predictive modeling efforts. Macrotidal flats are an important Naval battlespace environment.

NEAR REAL-TIME MONITORING OF THE INDIAN RIVER INLET SCOUR-HOLE EDGE EVOLUTION SEAWARD OF THE BRIDGE PIERS

James H. MacMahan, Assistant Professor
Department of Oceanography
Sponsor: University of Delaware

OBJECTIVE: Bridge pier scour is a common problem that occurs in riverine and tidal environments. One of the most noticeable and rapidly changing locations of bridge scour under tidal influence occurs in the

Indian River Inlet Bridge (IRIB) in Sussex County, Delaware. This collaborative project seeks to monitor the scour hole edge seaward of the IRIB piers. Typical bathymetry monitoring of the inlet occurs on multi-year time scales and does not allow for rapid, short-term processes to be realized in the broader context of long-term variability. In addition, the lack of short-term scour-hole information makes it difficult for managers and engineers to make informed decisions about bridge stability and safety. In this joint research effort, the main goal is to overcome the lack of short-term information by installing a near-real-time monitoring system that will image the sea bed adjacent to the bridge piers. In addition, current meter data will yield critical forcing conditions that can be related to scour-hole variability.

RIP CURRENT DYNAMICS IN A COMPLEX BEACH ENVIRONMENT

James H. MacMahan, Assistant Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: To collaboratively examine, through observations and advanced numerical modeling, the three-dimensional velocity field in rip current systems on a strongly forced, complex, natural sandy beach at temporal and spatial scales, including turbulent, incident wave band, infragravity, very-low frequency and mean currents.

SPATIAL AND TEMPORAL VARIABILITY OF GRAIN SIZE AND SMALL-SCALE MORPHOLOGY

James H. MacMahan, Assistant Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: To use an amphibious surf-zone crawler to test the hypothesis that the heterogeneity of coastal sub-aerial and sub-aqueous morphology on many scales is correlated with the heterogeneity in surface sediments, which influence the morphodynamics. The development and field evaluation of the surf-zone crawler encompasses a significant portion of this effort. The assessment of the surf-zone crawler platform and corresponding observations will be integrated into Naval predictive models for mine burial and Navy SEAL operations within the surf zone.

AOMIP: SYNTHESIS AND INTEGRATION ACTIVITIES TO IMPROVE MODELS AND REDUCE UNCERTAINTIES IN MODEL PREDICTIONS

Wieslaw Maslowski, Research Associate Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: The Arctic Ocean Model Intercomparison Project (AOMIP) is an international effort to determine the systematic errors in models of the Arctic Ocean forced with realistic atmospheric conditions. AOMIP involves the international ocean modeling community in a major test and intercomparison of model performance. The main goal of this project is to examine the behavior of different models and their ability to simulate past, present, and future variability of the Arctic Ocean climate and the major processes maintaining ocean dynamics.

OCEANOGRAPHY

APPLICATION OF PARALLEL OCEAN AND CLIMATE MODELS TO DECADE/CENTURY PREDICTION

**Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: Department of Energy**

OBJECTIVE: To use a set of global ocean and ocean/ice simulations at both eddy-resolving (0.1°) and eddy-permitting (0.2° - 0.4°) resolutions to understand the effects of using improved ocean and ice parameterizations, increased resolution, and the impact of ice itself on the ocean solution. Also, a high-resolution, regional Pan-Arctic coupled ocean/ice model will be used to test new ice parameterizations. This effort will further on-going research to develop a high-resolution, global coupled atmosphere/ocean/ice prediction system for Navy needs, which has been underway since 1999. The 0.1° global simulation will resolve both the eddy field and important narrow mean flows: quantities that are both important for Navy prediction.

COLLABORATIVE RESEARCH: ENVIRONMENTAL VARIABILITY, BOWHEAD WHALE DISTRIBUTIONS, AND INUPIAT SUBSISTENCE WHALING-LINKAGE AND RESILIENCE OF AN ALASKAN COASTAL SYSTEM

**Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation**

OBJECTIVE: The main hypothesis of this interdisciplinary project is that variation in environmental conditions may impact the success of the annual bowhead hunt through alteration of whale distribution and behavior, and through changes in wind patterns and ice extent that affect Native whalers' access to the whales. A comprehensive study of this Alaska coastal system is proposed to quantify whale-environment linkages and to understand how physical-biological coupling influences bowhead whale behavioral ecology and, ultimately, Alaska Native subsistence harvests.

A COMPREHENSIVE MODELING APPROACH TOWARDS UNDERSTANDING AND PREDICTING THE ALASKAN COASTAL SYSTEM RESPONSE TO CHANGES IN AN ICE-DIMINISHED ARCTIC

**Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research**

OBJECTIVE: To provide a system approach to advance the knowledge and predictive capability of the diverse impacts of changing sea-ice cover on the bio-physical marine environment of coastal Alaska and over the larger region of the western Arctic Ocean. This project will focus on seasonally ice-free Alaskan coasts and shelves.

This research is in direct support of the topic "Coastal Effects of a Diminished-Ice Arctic Ocean" and of littoral studies of interest to the U.S. Navy.

TOWARDS AN ADVANCED UNDERSTANDING AND PREDICTIVE CAPABILITY OF CLIMATE CHANGE IN THE ARCTIC USING A HIGH-RESOLUTION, REGIONAL ARCTIC-CLIMATE-SYSTEM MODEL

**Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: Department of Energy**

OBJECTIVE: To understand past and present and predict future changes of the Arctic climate system. In particular, to explore and quantify the coupled Arctic-climate system processes responsible for the recent observed and future predicted changes in Arctic sea-ice cover using a fully coupled system model.

TOWARDS PREDICTION OF ARCTIC SEA ICE-OCEAN-GLOBAL CLIMATE INTERACTIONS AT SEASONAL TO DECADAL SCALES

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: NASA Goddard Space Flight Center

OBJECTIVE: To address the Global Model limitations in representing Arctic sea ice and ocean conditions through identification of the primary physical and numerical requirements of future/improved GCMS; to understand the present and past several decades' conditions in the Arctic sea ice and ocean, with emphasis on variability in the total ice volume and freshwater content in the Arctic Ocean, as well as on sea ice and freshwater fluxes into the north Atlantic; and to predict future scenarios of a seasonally/partially sea-ice-free Arctic Ocean in response to atmospheric forcing derived from global/regional climate model predictions and/or using a combination of northern hemisphere weather indices extrapolated into the future.

THE 2009 INCITE PANEL

Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: Department of Energy

OBJECTIVE: Travel to participate in 2009 Department of Energy INCITE program.

AN ANALYSIS OF HF RADAR DATA FROM THE NORTHERN ADRIATIC SEA

Jeffrey D. Paduan, Professor
Department of Oceanography
Sponsor: CNR-ISDGM, Venice Italy and OGS, Trieste, Italy (expired)

OBJECTIVE: To work with Italian and NATO-sponsored research groups in the northern Adriatic Sea region to deploy and utilize high-frequency surface-current mapping systems.

SUMMARY: This project utilized funding from the CNR Istituto di Scienze Marine (ISMAR), Venice, Italy, to support analyses of ocean surface-current maps offshore of the Venice Lagoon produced from a three-site high-frequency (HF) radar network. Instrument siting and calibration were included, along with the analysis of a year-long record of hourly surface-current maps. The maps showed patterns of tidal currents, low-frequency currents, and recurring sub-mesoscale (~5 km) eddies features offshore of the Malamocco Inlet. The project also supported integration of these efforts with a second array of HF radar systems along the western Adriatic Sea. Support for a Ph.D. student at the University of Venice was included. During this year, the program extended eastward through a collaboration with Croatian scientists to cover the northeast Adriatic Sea.

PUBLICATION:

Gačić, M., V. Kovacevic, S. Cosoli, A. Mazzoldi, J.D. Paduan, I. Mosquera, and S. Yari, "Surface current patterns in front of the Venice Lagoon," *Estuarine, Coastal and Shelf Science*, 10.1016/j.ecss.2009.02.012, 2009.

KEYWORDS: HF Radar, Ocean Currents, Ecosystem Modeling, Cross Shore Exchange

THE COASTAL OCEAN CURRENTS MONITORING PROGRAM

Jeffrey D. Paduan, Professor

Department of Oceanography

Sponsor: State of California (via San Francisco State University)

OBJECTIVE: To demonstrate the viability of long-range high-frequency radar for mapping ocean currents out to 200 km from shore.

SUMMARY: This program is part of a multi-year, statewide project to instrument California with shore-based high-frequency (HF) radar ocean current mapping systems and to develop a surf-zone transport-monitoring system. The ambitious project is working to extend the mapping network that originated in Monterey Bay to cover the entire state in order to provide real-time mapping of surface transport for hazardous-spill mitigation and search-and-rescue operations, as well as archival support for dispersal-based management decisions. Professor Paduan and the Naval Postgraduate School are responsible for the installation and operation of ten HF radar sites from the Big Sur coastline to Half Moon Bay, as well as the interpretation of surf-zone wave and current data. The overall project is a critical demonstration project in California and nationwide for the growing efforts to establish an Integrated Ocean Observing System (IOOS).

PUBLICATIONS:

Kaplan, D.M., C. Halle, J. Paduan, and J.L. Largier, Surface currents during anomalous upwelling seasons off central California. *J. Geophys. Res.*, doi:10.1029/2009JC005382, 2009.

Laws, K., J.D. Paduan, and J. Vesecky, Estimation and assessment of errors in high-frequency radar ocean current measurements. *J. Oceanic and Atmos. Tech.*, 2009, in press.

Wang, Q., J. Kalogiros, S. Ramp, J. Paduan, G. Buzorius, and H. Jonsson, "Wind stress and coastal upwelling in the area of Monterey Bay observed during AOSN-II." *J. Phys Oc.*, 2009 (submitted and in review).

CONFERENCE PUBLICATION:

Zelenke, B., Moline, M.A., Jones, B.H., Ramp, S.R., Crawford, G.B., Largier, J.L., et al., "Evaluating Connectivity between Marine Protected Areas using CODAR High-Frequency Radar," *Proceedings of the IEEE Oceans '09*, Biloxi, Mississippi, 26-29 October 2009 (in press).

PRESENTATIONS:

Paduan, J.D. and Kaplan, D., "HF Radar-Derived Surface Currents during Anomalous Upwelling Seasons off Central California," 9th International Radiowave Oceanography Workshop (ROW-9), Split, Croatia, 19-22 May 2009.

Ryan, J.P., Scholin, C.A., Kudela, R.M., Gower, J.F.R., and Paduan, J.D., "A Phytoplankton Bloom Incubator in the Central California Current System," GEOHAB Modeling Workshop, Martin Ryan Institute, National University of Ireland, Galway, 15-19 June 2009.

Zelenke, B., Moline, M.A., Jones, B.H., Ramp, S.R., Crawford, G.B., Largier, J.L., et al., "Evaluating Connectivity between Marine Protected Areas using CODAR High-Frequency Radar," *IEEE Oceans '09*, Biloxi, Mississippi, 26-29 October 2009.

KEYWORDS: HF Radar, Ocean Currents, Air-Sea Interaction

OCEANOGRAPHY

CORE MOORING DATA SUPPORT

Jeffrey D. Paduan, Professor

Department of Oceanography

Sponsor: Monterey Bay Aquarium Research Institute

OBJECTIVE: To perform data processing, quality control, and delivery of meteorological and physical oceanographic data from MBARI moorings M1 and M2. A subset of mooring data, specifically surface and subsurface CTD, T-string, meteorological position, GPS, and currents (ADCP), will be processed to the appropriate engineering units and quality-controlled. This includes processing data collected from moorings, which MBARI designates as “core” data, including data collected before 1 January 2009. MBARI is currently collecting data from two moorings, designated M1 and M2, but historical data collected from mooring M3 and M4 are included in this scope of work.

CORE MOORING DATA SUPPORT

Jeffrey D. Paduan, Professor

Department of Oceanography

Sponsor: Monterey Bay Aquarium Research Institute

OBJECTIVE: To provide real-time quality-control feedback for physical oceanographic and meteorological observations being made on deep-ocean moorings in Monterey Bay.

SUMMARY: The specific activities of this sub-project involve data processing and quality assurance for physical oceanographic and meteorological sensors on real-time mooring platforms deployed in Monterey Bay. The moorings are maintained by the Monterey Bay Aquarium Research Institute (MBARI). Naval Postgraduate School personnel retrieve both real-time and post-recovery data from the sensors, quality control and reformat the data, and return the processed datasets to MBARI.

KEYWORDS: HF Radar, Ocean Currents, Observing Systems

DELIVERY AND QUALITY ASSURANCE OF SHORT-TERM TRAJECTORY FORECASTS FROM HF RADAR OBSERVATIONS

Jeffrey D. Paduan, Professor

Department of Oceanography

Sponsor: NOAA Coastal Response Research Center

OBJECTIVE: To quantify errors in high-frequency (HF) radar-derived trajectory estimates; and to document formats and procedures needed to effectively use those estimates within government oil-spill response agencies.

This project is a joint effort between researchers at the Naval Postgraduate School (NPS) and San Francisco State University. The project will develop, assess, and document the use of real-time ocean surface-current maps from HF radar installations. Specifically, the principal investigators (PIs) will evaluate the use of these data in support of oil-spill response activities. An extensive test of these capabilities was conducted in connection with the NOAA Safe Seas 2006 oil-spill exercise offshore San Francisco in August 2006. The PIs intend to conduct a systematic post-exercise evaluation and to document lessons learned. The PIs also intend to quantitatively assess the performance of the short-term (24-hour) surface-current prediction methodology that was developed for the Safe Seas 2006 exercise by comparing observed and predicted currents under a wide range of environmental conditions. To aid that assessment, a multi-day, multi-deployment field experiment using an array of GPS-tracked surface drifters will be conducted. Finally, results will be documented in the form of a package of recommendations and procedures for the integration of HF radar-derived products into real-time spill-response protocols.

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TECHNICAL REPORT:

Garfield, N., Paduan, J.D., and Ohlmann, C., "Delivery and Quality Assurance of Short-Term Trajectory Forecasts from HF Radar Observations -- Final Report to the Coastal Response Research Center," 34 pp., June 2009.

KEYWORDS: HF Radar, Ocean Currents, Oil Spill Response, Search and Rescue

RESEARCH VESSEL SUPPORT FOR METOC STUDENTS IN THE 2009 ACADEMIC YEAR

Jeffrey D. Paduan, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To support at-sea instructional experiences for students in the oceanography curricula at the Naval Postgraduate School, including time on nationally managed research vessels within the University National Oceanographic Laboratory System (UNOLS) Program during the 2009 academic year.

SUMMARY: A series of student cruises were conducted in 2009 in support of the graduate programs in the oceanography and meteorology programs.

KEYWORDS: Graduate Education, Oceanography, UNOLS

CAREER: FLUXES AND STRUCTURES IN DOUBLE-DIFFUSIVE CONVECTION

Timour Radko, Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To conduct numerical simulations of oceanic thermohaline staircases and explain their dynamics. These experiments will involve analysis of the acoustic scattering on the interfaces, a project of direct relevance to Navy research interests in general and to the interests of the Naval Postgraduate School Department of Oceanography in particular.

COLLABORATIVE RESEARCH: STUDIES OF THE INFLUENCE OF THE ANTARCTIC CIRCUMPOLAR CURRENT ON THE ATLANTIC MERIDIONAL CIRCULATION

Timour Radko, Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To conduct numerical simulations of the oceanic thermohaline circulation in the mid-latitude Atlantic and in the Antarctic Circumpolar Current. The main goal of this modeling effort is to explain the role of mesoscale variability in the dynamic connection of these two regions. Properties of ocean thermal fronts and eddies determine undersea warfare tactics in areas of high mesoscale activity; therefore, these efforts to predict its distribution and strength are directly related to Navy research interests in general and to the interests of the Naval Postgraduate School Department of Oceanography in particular.

NUMERICAL STUDIES OF DOUBLE-DIFFUSIVE CONVECTION IN THE INTERIOR OF GIANT PLANETS

Timour Radko, Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To conduct numerical simulations of double-diffusive convection, a major mixing process in the earth's oceans and in the interior of several giant planets. Inference from the theory and model runs will be used to formulate a parameterization scheme for the oceanic general-circulation models.

AN ARRAY OF AUTONOMOUS, OCEAN-FLUX BUOYS TO DIRECTLY OBSERVE TURBULENT, VERTICAL FLUXES OF HEAT, SALT, AND MOMENTUM AS A COMPONENT OF THE ARCTIC OBSERVING NETWORK

Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

SUMMARY: Observations from the repeated, multi-year-duration deployments of the AOFBS will lead to an improved understanding of the basic physical processes that are affecting the thermodynamic balance of the Arctic Ocean ice cover. It is this balance, considered throughout the basin, that will determine if the Arctic transitions to a state of greatly reduced or no perennial ice cover. The proposed collaborative ice-flow observatories will generate canonical datasets, previously attainable only from manned ice stations. These observations will serve as invaluable audit points for the testing and evaluation of regional and global models by providing a suite of data comparable to the most intensive manned camps, but with greater temporal and spatial coverage. The successful, long-term execution of the ice-based observatory effort has the potential to provide a transformative understanding of the loss of Arctic perennial ice cover and of the state of stability of the Arctic system. This project has impact on Naval coupled ocean/ice models of the rapidly changing, ice-covered Arctic Ocean.

COLLABORATIVE RESEARCH: BENTHIC LAYER GEOCHEMISTRY AND PHYSICS AT THE KILO NALU

Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: To study the diffusivity of rippled, sandy ocean beds forced by waves and currents. Bed diffusivity controls the micro particulate and geochemical fluxes between the sea bed and the ocean, and is strongly modulated by wave and current forcing above the bed. This project is a collaboration with geochemists, biologists, and ocean engineers at the University of Hawaii. The project will use a cabled observatory at Kilo Nalu, which is modeled on the Naval Postgraduate School MISO cabled observatory that has been maintained offshore of the campus for the last ten years.

SUMMARY: Software to extract the 3D bedform morphology timeseries surrounding the BCDVSP profiler has been developed for the rapid scanned laser developed in the principal investigator's research group and deployed at the Kilo Nalu experiment site during the 2007 experiment. Data from these two instruments are being used to characterize the flow field, turbulence levels, and bed porosity above a rippled sandy bed. A new dye injection system deployed during the experiment is being used to identify the preferred diffusive paths taken by fluid within the sand under ripple bedforms. Collaborative analyses of this comprehensive dataset is underway with a Continental Shelf research paper comparing the turbulent structure of mobile coral sand beds with those of quartz sand beds nearing completion.

PUBLICATION:

Sansone, F.J., G. Pawlak, T. Stanton, B.T. Glazer, M.A. McManus, E.H. DeCarlo, et al., Kilo Nalu – Physical/biogeochemical dynamics above and within permeable sediments. *Oceanography*, December 2008.

IPY: TOWARDS DEVELOPING AN ARCTIC OBSERVING NETWORK – AN ARRAY OF SURFACE BUOYS TO SAMPLE TURBULENT OCEAN HEAT AND SALT FLUXES DURING THE IPY

Timothy P. Stanton, Research Associate Professor

William Shaw, Research Assistant Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: Observations of vertical fluxes of heat, salt, and momentum between the ocean interior and surface are important to understanding and modeling processes that maintain perennial ice cover in the Arctic, particularly at a time of such rapid changes in ice coverage and volume. These changes have direct impact on strategic Naval issues, since most climate models, which depend on improved small-scale physical parameterizations, show perennial ice cover disappearing in the next 5 – 40 years, opening trans-Arctic sea lanes and altering defense requirements in the region. This research will continue ocean flux deployments in the central Arctic and extend deployment to the western Arctic in order to improve parameterizations of the complex ocean-ice-atmosphere processes in coupled models.

SUMMARY: Observations of upper ocean flux timeseries in the Arctic Basin continued this year with the deployment of three Naval Postgraduate School (NPS)-designed Ocean Flux Buoys (AOFBs) in the Arctic Basin in collaboration with five other research groups. This program is a component of the International Polar Year, an international collaborative effort to intensively observe and model ocean/ice processes at high latitudes. These observations are being made at a time of significant change in ice cover and volume of the perennial Arctic ice pack (particularly over the last four years), which appears to be responding to global-warming climatic pressures. A paper reporting results from these buoy observations has been published in the *Journal of Geophysical Research*, another paper summarizing summer heat fluxes near the North Pole has been completed, and an analysis of the SHEBA Beaufort Sea CTD and microstructure dataset has been published in the *Journal of Geophysical Research*.

PUBLICATIONS:

Shaw, W.J., T.P. Stanton, M.G. McPhee, J.H. Morison, and D.G. Martinson, 2009: The role of the upper ocean in the surface heat budget of the Arctic Ocean. *J. Geophys. Res.*, 114, C06012, 10.1029/2008JC004991.

Sirevaag, A., M.G. McPhee, J.H. Morison, W.J. Shaw, and T.P. Stanton, 2010: Wintertime mixed layer measurements at Maud Rise, Weddell Sea. *J. Geophys. Res.*, 115, C02009, doi:10.1029/2008JC005141.

Stanton, T.P., W.J. Shaw, and J. Hutchings, 2008: Summer ocean-to-ice heat flux in the central Arctic: 2002-2008. *J. Geophys. Res.*, submitted.

CONFERENCE PRESENTATIONS:

Batteen, M.L., Stanton, T.P., and Maslowski, W., “Climate Change and Sustainability: Connecting Atmospheric, Ocean, and Climate Science with Public Literacy,” Forum on Public Policy Online, Summer 2008 Edition, January 2009.

Shaw, W.J. and Stanton, T.P., “Vertical Diffusivity of the Western Arctic Ocean Pycnocline,” Ocean Sciences Meeting, Portland, Oregon, 2010.

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Stanton, T.P. and Shaw, W.J., "Upper Ocean Heating Processes in the Thinning Ice of the West and Central Arctic Ocean," Ocean Sciences Meeting, Portland, Oregon, 2010.

OBSERVATIONS OF UPPER OCEAN TEMPERATURE, SALINITY, AND PH STRUCTURE IN THE CENTRAL ARCTIC

Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The Arctic Ocean is currently experiencing a number of environmental changes associated with climate change, including rapidly declining summertime sea-ice extents and melting of permafrost. Reduced ice cover allows more efficient exchange between the ocean and atmosphere, and permafrost melt leads to larger chemical transports from the land to the ocean. Both of these effects are likely to affect the pH, salinity, and temperature of the Arctic Ocean surface layer. This research will measure the spatial and temporal variability of the upper Arctic Ocean to document these ongoing changes and assess the impact of the changes on the attenuation of acoustic energy in the ocean. This work directly impacts medium- and long-range acoustic propagation models.

OBSERVATIONS OF UPPER OCEAN TEMPERATURE, SALINITY, AND PH STRUCTURE IN THE CENTRAL ARCTIC

Timothy P. Stanton, Research Associate Professor
William Shaw, Research Assistant Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: This is a study of the relative roles of changing upper ocean structure and increasing pH to acoustic propagation variability and path loss in the central Arctic. While the increase in pH is thought to have only a small impact on acoustic propagation, there is very little data to use in modeling the effects of pH. This field study will provide funding for two students to participate in the Navy ICEx2009 in March 2009, organized by the Arctic Submarine Lab.

SUMMARY: The two students, Steve Col and Russ Ingersoll, successfully deployed a CTD profiler equipped with a pH sensor at the ICEx ice camp in the Beaufort Sea using a lightweight, battery-operated winch fabricated at the Naval Postgraduate School. They made high-resolution profile time series during the two-week experiment at the camp, and were able to measure along one 120 km helicopter survey-line away from the camp to look at lateral gradients in the upper ocean. One National Science Foundation-funded Ocean Flux Buoy equipped with a pH sensor was deployed from the ice floe, and it provided an extended space/time series of ocean mixed-layer pH as the buoy drifted west and north in the Beaufort Sea during the following six months. Two theses and papers are being written by the students. The first is an acoustic modeling study of 100 km path-length propagation at 100 Hz, 1 KHz, and 10 KHz, focusing on both upper ocean structure variability and the measured pH profiles. This will be submitted to JASA for publication. The second study of upper ocean salinity changes over the last 30 years will get underway in early 2010.

OCEAN-ICE INTERACTION IN THE AMUNDSEN SEA: THE KEYSTONE OF WEST ANTARCTIC STABILITY

Timothy P. Stanton, Research Associate Professor
William Shaw, Research Assistant Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: Integrated oceanographic and glaciological field studies are being linked with regional and local modeling activities to advance the ability to predict the future behavior of ice sheets, particularly that

portion of West Antarctica that drains into the Amundsen Sea. The Naval Postgraduate School (NPS) component of this large, collaborative project (including NASA and British Antarctic Survey participants) is to develop, deploy, and analyze data from a highly specialized, ocean-flux profiler that will operate in the ocean cavity below the 500m-thick Pine Island Glacier Ice Shelf. The profiler measures turbulent fluxes of heat, salt, and momentum near the ice/ocean interface, and once each day measures the ocean structure and lateral fluxes across the ocean cavity. The societal and Naval importance is the need to predict future sea levels, which impacts all shore facilities and littoral regions. Without a process-based understanding of the interaction of the ocean on the ice sheet discharge, supported by measurements, and its incorporation into predictive models' sea-level predictions, large errors will remain in sea-level rise predictions.

SUMMARY: This year's effort focused on lab and field testing of the prototype profiler. Communication and data acquisition software was completed, including the development and testing of the surface infrastructure package that provides two-way communication between the profiler and NPS. Field tests were conducted during July in Crater Lake, Oregon, exploiting the 560m-deep basin with hydrothermal activity, in collaboration with the National Park Service. A supplemental proposal was funded to perform a successful deployment of the prototype profiler through a hot water drilled hole through the 200m-thick Ross Ice Shelf. This work involves collaboration with colleagues from NASA, BAS, NYU, OSU, and UW. An invited talk was presented to scientists at NIWA in New Zealand following the deployment near McMurdo Station, and interaction with this group is facilitating a collaborative test in the 2010 season.

OFFSHORE SANDBAR MIGRATION IN THE NEAR SHORE AND SURF ZONE

Timothy P. Stanton, Research Associate Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: To study the long-term dynamics of sandbar migration using a 1/8-scale wave flume with artificial sediments and programmable wave fields. This work is being executed through a CRADA with Delft Hydraulic in the Netherlands, using their wave flume and PIV system, and a very high-resolution acoustic Doppler profiler developed in the principal investigator's (PI) research group to measure 2D current, sediment load, and turbulence profiles with 2mm vertical resolution. The work is primarily being done by a Ph.D. student at Delft, who has participated in three of the field experiments.

SUMMARY: A 5 MHz, two-axis Doppler profiler was designed and implemented for use in the Delft wave flume, based on a board set developed for the PI's BVDVSP coherent bistatic Doppler profiler. Ph.D. student Martijn Henrique visited during the year to learn how to use the instrument and participate in backscatter and velocity calibrations in the lab. He has been using the profiler in the wave flume since October 2009, and will be making a series of bar evolution measurements early in 2010. This project provides an excellent opportunity to compare the acoustic velocity profile measurements with particle imaging velocimetry systems (PIV) while studying the wave-forced sediment transport that leads to bar migration in the surf zone.

ONSHORE SANDBAR MITIGATION IN THE NEAR SHORE AND SURF ZONE

Timothy P. Stanton, Research Associate Professor

Department of Oceanography

Sponsor: Delft University of Technology

OBJECTIVE: To examine and model the physical mechanisms responsible for onshore sandbar migration. The collaborators will conduct a wave flume experiment to examine and determine the physical processes responsible for onshore sandbar migration in the near shore using small-scale acoustic Doppler current and sediment load profiling instruments developed at the Naval Postgraduate School. The data collected and the new knowledge gained will be used to develop model formulations that are suitable for implementation in operational computer models for the prediction of near shore morphodynamic evolution. These models will be utilized to improve the design of coastal harbors and structures.

RCEX: RIP CURRENT EXPERIMENT ON THREE-DIMENSIONAL NEAR-SHORE CIRCULATION

Timothy P. Stanton, Research Associate Professor

James H. MacMahan, Assistant Professor

Edward Thornton, Distinguished Professor Emeritus

Department of Oceanography

Sponsor: Office of Naval Research Coastal Geosciences

OBJECTIVE: To observe the 3D current circulation of rip channel/shoal systems in the near shore. A combination of Eulerian, Lagrangian, and remote sensing methods will be used by Naval Postgraduate School faculty and collaborators at a site within Monterey Bay that maintains incised rip channels in the surf zone. A parallel modeling effort will extend the observations using the Delft 3D Nearshore Circulation Model to include vertical structure effects. This model is being transitioned as the new Navy surf-zone circulation model.

SUMMARY: Analysis of the spring 2007 observations of current circulation and boundary layer processes in Monterey Bay continued in 2009. The focus was on co-principal investigator Jamie MacMahan's drifter deployments, combined with the long-shore PUV array and cross-shore ADCP current profile array deployed across a rip-channel/shoal cell. The short-duration bottom-boundary-layer measurements were analyzed to determine off-shore sediment-transport rates within a rip channel. A major finding of this surf-zone circulation study by MacMahan's drifters was the presence of closed circulation cells with offshore flow in the rip channels and nearly balanced onshore flow over the shoals.

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Brown, J., J.H. MacMahan, A. Reniers, and E. Thornton, Surfzone diffusivity on a rip channel beach. *J. Geophys. Res.*, doi:10.1029/2008JC005158, 2009.

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PRESENTATION:

Geiman, J.D., Kirby, J.T., Reniers, A.J.H.M., MacMahan, J.H., Brown, J.W., Brown, J.A., et al., "Coherence of Eddies in a Rip Channelled Surfzone, Lagrangian Analysis and Prediction of Coastal and Ocean Dynamics," La Londe-les-Maures, France, 2009.

TOWARD A PREDICTIVE MODEL OF ARCTIC COASTAL RETREAT IN A WARMING CLIMATE, BEAUFORT SEA, ALASKA

Timothy P. Stanton, Research Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research/NOPP

OBJECTIVE: To begin developing a predictive model of Arctic coastal dynamics that integrates retrospective analyses of remotely sensed and on-the-ground environmental data, new observations and

monitoring of inner shelf and near shore processes, and numerical models that explicitly address the feedbacks between landscape and seascape responses to climatic change in the Arctic. The Naval Postgraduate School (NPS) component has provided high-resolution surface gravity wave, tide, and temperature observations along a cross shelf array at a location along Alaska's northern coast east of Barrow. The resulting coastal model will help Navy wave prediction and coastal modeling efforts as the perennial ice cover in the Arctic Ocean continues to recede and increases wave-forced erosion of the fragile coastline.

SUMMARY: During the second year of this project, four autonomous pressure sensor systems were successfully deployed, after logistics and severe early season ice conditions and difficulties prevented deployment in year one. These systems are boat-deployable by one person, and the researchers were able to coordinate work boat support for deployment and retrieval this year. The sensors continuously sampled the wave field for two months at an 8Hz sample rate. These observations are to be used to spectrally characterize wave transformation across the shallow, muddy coastal shelf offshore from the rapidly eroding permafrost bluffs that are the focus of this project. Several storm systems were observed, and the large fetch due to the large open-water area in the Beaufort Sea in late summer resulted in eight-second period waves impinging on the coast. A paper describing these wave observations is in preparation.

A FEASIBILITY STUDY FOR UNDERSTANDING CLIMATE UNCERTAINTY WITH AN OCEAN FOCUS

Robin Tokmakian, Research Associate Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: To 1) run a designed experiment using the ocean and ice components of the Community Climate System Model (CCSM), 2) develop a statistical analysis of the uncertainty of the model components as related to their parameter space, and 3) extend what is learned about the model's uncertainties to the model at higher resolution.

SUMMARY: The principal investigators (PIs) have completed the initial analysis of ten runs of the model (100 years each) and have begun to create the ensemble of 100 runs at 100 years each. The analysis software has been developed to explore the uncertainty in the initial ten-member ensemble. Various metrics are being examined to determine how effective they are in characterizing a model's parameter uncertainty space. The initial set of analyses shows that the application of these advanced statistical methods can be useful when applied to a general circulation model with both linear and non-linear responses in its solution. A discussion of the methodology is described in Challenor and Tokmakian (2010).

Designing an experiment to explicitly determine the formal uncertainty in a model requires a set of steps. The methods discussed in this paper can be applied to any number of problems and situations using models of varying complexity and temporal extent. This paper describes the results from an initial experiment using a limited ensemble as applied to the ocean component of a complex general circulation climate model. The uncertainty in a model is a combination of the uncertainty in the initial conditions, the parameter space, and the model structure. "Statistical Analysis of Computer Code Output" (SACCO) methods can be used to explore uncertainties associated with such complex models. A relatively small member ensemble (10-100 members) of the complex model is combined with an emulator to expand the limited PDF of outcomes from the physical model to a full PDF that is representative of a 1000-member ensemble. An emulator is a tool to investigate the uncertainty characteristics of the model and its outcomes; it is not a replacement for the model itself. The full PDF can then be used to determine uncertainty values associated with a metric determined by or computed from the outputs of the physical model. To test the feasibility of applying the method to complex general circulation climate models, the PIs determine the uncertainty applied to only the ocean component of the CCSM climate model as a function of its parameter space, a "perturbed physics" scenario. The PIs define the values of the parameters to be used by an ensemble member using a Sobol sequence, a quasi-random method for determining a uniform distribution for a set of parameters. The designed experiment will eventually use an ensemble of 100 model runs, each 100 years in length. An initial ten-member ensemble has been created to determine the extent and quality of the parameter space. Ten parameters are varied within this ensemble. The PIs will eventually look at the

resulting PDFs for the following metrics: mean MOC, mean SST, globally and regionally, and mixed layer depth for several ocean basins/locations. Using the outcomes from this small ensemble, the PIs describe the methodology, the results using this small ensemble, and how the design experiment should be extended to the full and complete 100-member ensemble. The effort to create a 100-member ensemble for analysis of the ocean and ice component parameter space has begun (20% complete). Ongoing analysis as the experiment progresses shows that the methodology of a design experiment incorporating the use of an emulator will provide useful results for understanding the underlying uncertainty in the ocean model's parameter space.

The research used the resources of both the NPS high-performance computer, Hamming, as well as significant resources at the National Center for Atmospheric Research.

DEPARTMENT OF OCEANOGRAPHY

**2009
Faculty Publications
and Presentations**

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Chu, P.C. and Hsieh, C.P., "Multifractal Thermal Structure in the Western Philippine Sea Upper Layer," American Geophysical Union Joint Assembly, Toronto, Canada, 24-27 May 2009.

Chu, P.C. and Kuo, Y.-H., "Biophysical Variability in the Kuroshio Extension from Altimeter and SeaWiFS," IEEE/MTS OCEANS 2009, Biloxi, Mississippi, 26-29 October 2009.

Chu, P.C., Ivanov, L., and Fan, C.W., "Optimal Spectral Decomposition (OSD) for Observational Ocean Data Analysis," Thirteenth Symposium on Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, American Meteorological Society, Phoenix, Arizona, 11-15 January 2009.

Chu, P.C., Sun, C., and Fan, C.-W., "Detection of Thermohaline Structure and Meridional Overturning Circulation Above and Below the Ocean Surface," Twenty First Conference on Climate Variability and Change, American Meteorological Society, Phoenix, Arizona, 11-15 January 2009.

Chu, P.C., Sun, C., and Fan, C.W., "Observations of Meridional Overturning Circulation Above and Below the Ocean Surface," American Geophysical Union Fall Meeting, San Francisco, California, 14-18 December 2009.

Chu, P.C., Almquist, J.B., Gefken, P., and Watson, K., "Underwater Bomb Trajectory Prediction for Stand-Off Assault Breaching Weapon Fuse Improvement (SOABWFI)," European Undersea Defense Technology – Europe, Carnes, France, 9-11 June 2009.

Chu, P.C., Ivanov, L.M., Melnichenko, O.V., and Wells, N.C., "Rossby Wave Propagation in the Tropical North Atlantic Observed from Argo Floats," International Association of Physical Sciences of Oceans, Montreal, Canada, 20-24 July 2009.

Chu, P.C., Kyriakidis, K., Haeger, S.D., and Ward, M., "Tidal Effect on Chemical Spill in San Diego Bay," International Conference on Coastal Management, Malta, 14-16 September 2009.

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Chu, P.C., 2009: First passage time analysis for climate prediction. In: *Stochastic Physics and Climate Modeling*, edited by T.N. Palmer and P. Williams, Chapter 6, Cambridge University Press (ISBN-13:9780521761055).

Ivanov, L.M., C.A. Collins, 2009: Modal decomposition of oceanic circulation: Applications for high-resolution models and Lagrangian data, In: *Ocean Circulation and El Niño: New Research*, edited by J.A. Long and D.S. Wells, Chapter 2, Nova Science Publishers, Inc., New York.

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Hildebrand, J., "Marine Mammal Acoustic Monitoring and Habitat Investigation, Southern California Offshore Region," Naval Postgraduate School Technical Report, NPS-OC-09-006, 57 pp., June 2009.

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Mellinger, D., "Datasets of Odontocete Sounds Annotated for Developing Automatic Detection Methods," Naval Postgraduate School Technical Report, NPS-OC-09-008, 22 pp., July 2009.

Oleson, E.M., Calambokidis, J., Falcone, E., Schorr, G., and Hildebrand, J.A., "Acoustic and Visual Monitoring for Cetaceans along the Outer Washington Coast," Naval Postgraduate School Technical Report, NPS-OC-09-001, 35 pp., March 2009.

Rago, T.A., Michisaki, R., Marinovic, B., Blum, M., and Whitaker, K., "Physical, Nutrient, and Biological Measurements of Coastal Waters off Central California in October 2008," Naval Postgraduate School Technical Report, NPS-OC-09-004, 73 pp., May 2009.

Rago, T.A., Michisaki, R., Marinovic, B., Blum, M., and Whitaker, K., "Physical, Nutrient, and Biological Measurements of Coastal Waters off Central California in January 2009," Naval Postgraduate School Technical Report, NPS-OC-09-009, 46 pp., November 2009.

Rone, B.K., Douglas, A.B., Clapham, P., Martinez, A., Morse, L.J., and Calambokidis, J., "Cruise Report for the April 2009 Gulf of Alaska Line Transect Survey (GOALS) in the Navy Training Exercise Area," Naval Postgraduate School Technical Report, NPS-OC-09-007, 31 pp., June 2009.

Stafford, K.M., "Monitoring Cetaceans in the North Pacific," Naval Postgraduate School Technical Report, NPS-OC-09-003, 10 pp., April 2009.

**DEPARTMENT OF
PHYSICS**

**JAMES H. LUSCOMBE
CHAIRMAN**

PHYSICS

OVERVIEW:

The Department of Physics has unique resources and faculty expertise in combat systems technologies, including sensor, acoustic, and weapon systems.

CURRICULA SERVED:

- Combat Systems Science and Technology
- Undersea Warfare
- Space Systems Engineering, Space Systems Operations
- Electronic Warfare, Information Warfare

DEGREES GRANTED:

- Master's and Ph.D. degrees in Physics, Applied Physics, and Engineering Acoustics

RESEARCH THRUSTS:

- Optical and Electromagnetic Signal Propagation and Detection
- Weapons and Weapons Effects
- Underwater Acoustics and Communications
- Physical Acoustics
- Free-Electron Laser Physics
- Accelerator Physics
- Railgun Technologies
- Explosive Detonation Physics
- Dynamic Materials Properties
- MEMS-Based Sensors and Nanotechnologies
- Novel Detector and Sensor Development
- Autonomous Robotics
- Remote Sensing
- Radar Imaging, Non-Cooperative Target Recognition
- Terahertz Radiation, Sources and Imaging
- Physics of Networks
- Quantum-Well Infrared Detectors
- Quantum Cascade Lasers

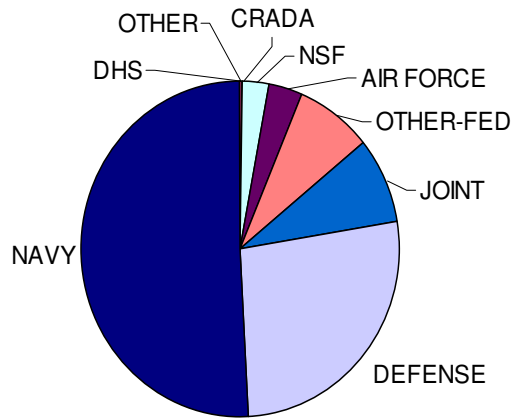
RESEARCH FACILITIES:

The Department of Physics has numerous advanced research facilities, including: a dedicated free-electron laser and linear accelerator facility; a gas gun laboratory; a railgun laboratory; a large, acoustic anechoic chamber; underwater acoustic tank facilities; a class 1000 clean room; a sensors research lab (including a laser vibrometer, a Fourier transform infrared spectroscopy, and a low-temperature photocurrent measurement system); a dome for telescope systems; and several advanced electron microscopes (a JEOL scanning electron microscope with variable temperature cathodoluminescence and transport imaging capabilities, a NovelX scanning electron microscope, and a Nanonics atomic force microscope with nearfield optical-scanning capability).

PHYSICS

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Physics is provided below:



Size of Program: \$8.9M

PHYSICS

James H. Luscombe
Professor and Chairman
831-656-2941
luscombe@nps.edu

Bruce Denardo
Associate Professor and Associate Chairman of Research
831-656-2952
denardo@nps.edu

Eric H. Adint
Research Associate
831-656-3440
ehadint@nps.edu

Nancy M. Haegel
Distinguished Professor
831-656-3954
nmhaegel@nps.edu

Angela M. Puetz
Research Associate
831-656-3330
ampuetz@nps.edu

Robert L. Armstead
Associate Professor
831-656-2125
armsted@nps.edu

Robert S. Hixson
Professor
831-656-2121
rshixson@nps.edu

Joseph A. Rice
Research Professor and
SSC San Diego Engineering
Acoustics Chairman
831-656-2982
rice@nps.edu

Steven R. Baker
Associate Professor
831-656-2732
srbaker@nps.edu

Richard M. Harkins
Senior Lecturer
831-656-2828
rharkins@nps.edu

Daria Siciliano
Post Doctoral Researcher
831-656-3330
dsicilia@nps.edu

Joseph Blau
Research Associate Professor
831-656-2635
blau@nps.edu

Raquel Herold
Research Associate
831-656-3124
rherold@nps.edu

Jose O. Sinibaldi
Research Associate Professor
831-656-2601
josiniba@nps.edu

Brett Borden
Professor
831-656-2855
bhborden@nps.edu

Daphne Kapolka
Senior Lecturer
831-656-1825
dkapolka@nps.edu

Craig F. Smith
LLNL Chair Professor of
Physics
831-656-2185
cfsmith@nps.edu

Ronald E. Brown
Research Professor
831-656-2635
rebrown@nps.edu

Gamani Karunasiri
Professor
831-656-2886
karunasiri@nps.edu

Kevin B. Smith
Professor
831-656-2107
kbsmith@nps.edu

William B. Colson
Distinguished Professor
831-656-2765
colson@nps.edu

Andres Larraza
Associate Professor
831-656-3007
larraza@nps.edu

Richard Swent
Research Associate Professor
831-656-2872
rlswent@nps.edu

Peter Crooker
Senior Lecturer
831-656-2232
ppcrooke@nps.edu

William B. Maier
Senior Lecturer
831-656-2806
maier@nps.edu

David Trask
Colonel, USAF (Ret.)
MASINT Chair
831-656-2219
dmtrask@nps.edu

D. Scott Davis
Associate Professor
831-656-2877
sdavis@nps.edu

Richard C. Olsen
Professor
831-656-2019
olsen@nps.edu

PHYSICS

Donald L. Walters
Professor
831-656-2267
walters@nps.edu

PHYSICS

MODELING AND SIMULATION OF ACTIVE SONAR TRANSDUCER ARRAY ELEMENTS AND THEIR INTERACTION

Steven R. Baker, Associate Professor
Department of Physics

Sponsor: L-3 Communications, Inc., Ocean Systems Division (L3-OS)

OBJECTIVE: To develop and utilize numerical, computational modeling tools to analyze and predict the performance of arrays comprised of clusters of close-packed sonar projectors. Such geometry could be utilized to increase an array's source level and so increase a sonar system's detection range. Tasks undertaken by the Naval Postgraduate School (NPS) in FY09 were: 1) the development of a COMSOL Multiphysics model of a bilaminar flexural disk sonar transducer of interest; 2) computation of the diffraction constant of the transducer using the model; 3) computation of the mutual radiation impedance between pairs of these transducers in various configurations using the model and using Baker's approximation; and 4) comparison of the results of task three with the results of the mutual radiation impedance computed using Pritchard's approximation.

SUMMARY: Three axisymmetric finite-element models of the sonar projector of interest, each of a varying degree of complexity, were developed using the COMSOL Multiphysics computer code, with dimension and material property data provided by L3-OS and obtained from other sources. Model material properties were manually and iteratively slightly adjusted to obtain the best possible agreement between model-computed and measured *TVR*, *G*, and *B* data provided by L3-OS. Excellent agreement was obtained for all three finite-element models. Using the most detailed finite-element model, further electroacoustical quantities of interest were computed, e.g., *TVR* beam pattern, diffraction constant, acoustical radiation self- and transfer impedances. A comparison was made between the acoustical radiation transfer impedance computed using Professor Baker's far-field approximation and that computed using the so-called Pritchard approximation. These computations were made as a function of polar angle with respect to a fixed projector, between it and a second projector held in either a parallel or perpendicular orientation relative to the first. Values of the acoustical radiation transfer impedance computed using the Pritchard approximation were found to compare satisfactorily with those computed using Baker's (more rigorous) approximation.

TECHNICAL REPORT:

Baker, S.R., "Axisymmetric Finite-Element Modeling of a Bilaminar Flexural Disk Sonar Projector Element using the COMSOL Multiphysics Code," Naval Postgraduate School Technical Report, NPS-97-09-001, December 2009.

KEYWORDS: Flexural Disk Sonar Projector, Finite-Element Modeling, Radiation Impedance

VIBRATION MEASUREMENTS ON PHALANX BLOCK 1B CIWS DURING LIVE-FIRE TESTING, FY2008

Steven R. Baker, Associate Professor
Department of Physics

Sponsor: Naval Sea Systems Command

OBJECTIVE: To participate in the collection of vibration data at selected locations on the PHALANX Block 1B Close-In Weapons System (CIWS) during live-fire testing conducted in FY08; to analyze the linear vibration measurements using MATLAB and to report results in a Naval Postgraduate School technical report; and to create a DVD archive of the linear vibration measurements, including the raw data, the MATLAB code, and the technical report.

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VIBRATION MEASUREMENTS ON PHALANX BLOCK 1B CIWS DURING LIVE-FIRE TESTING, FY2009

**Steven R. Baker, Associate Professor
Department of Physics**

Sponsor: Naval Sea Systems Command

OBJECTIVE: 1) To participate in the collection of vibration data at selected locations on the PHALANX Block 1B Close-In Weapons System (CIWS) during live-fire testing to be conducted in FY09; 2) to analyze the linear vibration measurements using MATLAB and to report the results in a Naval Postgraduate School technical report; and 3) to create a DVD archive of the linear vibration measurements, including the raw data, the MATLAB code, and the technical report.

SUMMARY: Live-fire testing of a PHALANX Close-In Weapon System was conducted on 17 and 18 August 2009 at China Lake. The primary purpose of the testing was to gather linear accelerometer vibration data at the same locations and under the same collection conditions (as best as possible) as the Naval Postgraduate School (NPS) collected during a similar live-fire exercise conducted in 1996. The main difference here was that both the older MK149 rounds and the newer MK244 rounds were fired, whereas only the MK149 rounds were available in 1996. Also, a new FLIR camera prototype was employed. The goal of the vibration testing was to determine whether or not the use of the newer (MK244) rounds results in increased vibration levels being transmitted to the FLIR camera. The results of NPS' vibration analysis will be considered by NAVSEA in writing the procurement specifications for a new FLIR camera. NPS participated in this testing and received the linear accelerometer vibration data for analysis. However, funding for a thorough analysis effort was not available in FY09. Instead, a "quick-look" statistical analysis of the vibration data was performed in FY09. A more thorough, spectral analysis of the data will be performed in FY10.

PUBLICATION:

Baker, S.R., "Quick-Look Comparison of Running Power-Averaged RMS Linear Acceleration Measured for MK149 and MK244 Fired Rounds -- Data from Live-Fire Exercises Conducted 18 August 2009 at China Lake (Jitter Test) on PHALANX CIWS Block 1B, System 347," letter report prepared for and sent to NAVSEA, September 2009.

KEYWORDS: PHALANX, Close-In Weapons System, CIWS, Structural Dynamics, Vibration

THE USE OF POLARIMETRIC IMAGERY FOR MARITIME DOMAIN AWARENESS

**LT Brian M. Barrick, USA, NPS Student
Department of Physics**

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To examine the further exploitation of polarimetric imaging capabilities towards improving the functionality and depth of U.S. collection capabilities. Specifically, this research will focus on the application of polarimetric imaging techniques towards specific problem sets within the intelligence community by leveraging existing datasets/field-work from SPAWAR SSC and the Navy and Air Force TENCAP programs. This research will include consideration of polarimetric imaging capabilities, such as cost, improving the end-user product, and overall functionality. This research will also consider non-technical aspects of polarimetric imaging capabilities by developing recommendations to implement polarimetric imaging capabilities into existing data collection capabilities.

PHYSICS

UNDERWATER ACOUSTIC DETECTION AND TRACKING OF SELF-PROPELLED SEMI-SUBMERSIBLES

LT Jeremy S. Biediger, USN, NPS Student
Department of Physics

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To coordinate with JIATF-S to deploy and test Seaweb networked acoustic sensors for detection and tracking of self-propelled semi-submersibles.

PULSED DETONATION ENGINE DEVELOPMENT/QUALIFICATION STUDIES

Christopher M. Brophy, Associate Professor
Department of Mechanical and Aerospace Engineering
Jose O. Sinibaldi, Research Associate Professor
Sponsor: Office of Naval Research

OBJECTIVE: Over the previous five years, the Naval Postgraduate School has developed a continuous-airflow Pulse Detonation Engine (PDE) geometry for the evaluation of the PDE cycle performance and operation using military relevant fuels. Research efforts over that period have involved numerous single-shot detonation experiments to evaluate selected areas of concern for a multi-cycle engine. Specifically, a great deal of time has been spent on the detonation initiation of various mixtures, the design and characterization of initiator combustors, and the subsequent diffraction of a detonation from a smaller to a larger combustor. The use of a highly-energetic initiator was determined to be a viable technique to rapidly and reliably initiate less sensitive mixtures involving heavy hydrocarbons and air. The current objectives are to determine the operational limits and performance of a valveless PDE operation on ethylene and JP10 fuels with air and to investigate the characteristics and applicability of a transient plasma ignition strategy for the effective initiation of detonations in fuel/air mixtures.

ADVANCED METHODS IN RADAR IMAGING

Brett H. Borden, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To apply generalized back-projection methods to the problem of imaging targets (including moving targets) which are illuminated by arbitrary waveforms by radar sensors of arbitrary configuration.

ADVANCED METHODS IN RADAR IMAGING

Brett H. Borden, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To examine the nature of radar image artifacts and their relationship to scattering model mismatch with radar measurements. To develop a generalized radar-imaging model that allows for arbitrary pulse shape and collection geometries (including moving targets).

SUMMARY: The research, now in its final year, has successfully developed a generalized radar-imaging theory appropriate to: 1) moving and stationary targets, 2) multistatic radar environments, and 3) general waveforms. Moreover, the theory reduces to all known traditional radar-imaging methods in the appropriate data limits. The image quality for this approach has been characterized by a generalized image point spread function (PSF), which has been shown to be related (in a non-trivial way) to the radar ambiguity function. Future work will concentrate on exploring the practical nature of this PSF.

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DETONABLE LIQUID TECHNOLOGIES FOR EOD/SAFE AND ARM

Ronald E. Brown, Research Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To develop a safe, reliable device for destroying explosive ordnance in situ that minimizes manufacturing costs, storage, assembly, and operational hazards. Previous research efforts have demonstrated the potential effectiveness of a baseline charge against typical explosive threats based on experimental and computational investigations, and have explored approaches for further enhancing performance and safety. Secondary objectives of this proposal are focused on exploiting and further developing these liquid-explosive technologies.

DETONABLE LIQUID TECHNOLOGY FOR EOD AND SAFE AND ARM

Ronald E. Brown, Research Professor

Jose O. Sinibaldi, Research Associate Professor

Department of Physics

Sponsor: Office of Naval Research

SUMMARY: The development of a low-cost precision shaped-charge device for surgically neutralizing explosive ordnance continued during 2009. A computational performance baseline was established and is being used as the basis for meeting the requirements for impact initiating encased TNT, which is considered to be the most difficult UXO target. Negotiations are on-going with the Pacific Scientific Energetic Materials Company for transitioning the technology for military and commercial application.

THE EFFECTS OF HYDRO-REACTIVE JETTING

Ronald E. Brown, Research Professor

Jose O. Sinibaldi, Research Associate Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To develop a clearer understanding of the effect of rapid chemical reaction during the hypervelocity impact of combustible jet-rods against submerged targets.

SUMMARY: This preliminary investigation showed that chemical energy can be effectively coupled into a target during the penetration process, if exothermal reaction is fast enough to compete with the penetration process. This conclusion is based on a best-case situation where a hydro-reactive jet-rod instantaneously reacts during impact and subsequent erosive backflow where virgin metal is continuously exposed to water. Aluminum is used because its reaction with water is one of the most exothermic among hydro-reactive metals, and because its dynamic ductility makes it an attractive liner material for an intended application. These results show that it might be possible to achieve hole enlargements slightly greater than 50 percent over that from kinetic energy coupling alone. There is also evidence that the hydrodynamic pressures produced during chemical reaction might be sufficient to cause the deformation of structures laterally displaced from a reacting rod.

IMPROVING IM PERFORMANCE (DISCLOSURE SENSITIVE)

Ronald E. Brown, Research Professor

Department of Physics

Sponsor: Office of Naval Research

SUMMARY: Over the last 25 months, a novel and unique technique for accelerating and sustaining high rates of detonation of any explosive were experimentally demonstrated, confirming the predictive accuracies of developed theoretical and computational techniques. Two experiments performed this year highlight the potential applicability of the process for increasing the rate and total directed energy output,

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decreasing collateral damage potential, and converting extremely insensitive energetic materials to explosive behavior. Detonation velocity increases of 35 and 64 percent from a high energy and extremely insensitive explosive, respectively, resulted from experiments conducted at the Lawrence Livermore National Laboratory and the U.S. Army's AP Hill facilities. Peak pressure elevations of up to 300 percent of the respective Chapman-Jouguet conditions far exceed the resolution capability of conventional piezo-electric transducers, as confirmed from observation.

The Office of Naval Research is funding a 2010 program directed towards demonstrating the applicability of the technology for enhancing shaped charge performance.

IMPROVING IM AND TERMINAL PERFORMANCE OF THE MK82 (EXPLOITATION OF TECHNOLOGIES DEMONSTRATED UNDER N00)

Ronald E. Brown, Research Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To demonstrate the general applicability of recently developed technology for improving the insensitivity and terminal performance of explosive warheads, specifically the MK82 bomb.

INSENSITIVE MUNITION: DEMONSTRATION OF A NOVEL INITIATION TECHNIQUE FOR EXPLOSIVE INITIATION AND OUTPUT POWER AMPLIFICATION

Ronald E. Brown, Research Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To experimentally demonstrate the applicability of a recently developed technology for initiating and amplifying the detonation power output of an insensitive explosive at less than critical diameter.

AN INVESTIGATION OF THE EFFECT OF HYDRO-REACTION DURING HYPERVELOCITY IMPACT

Ronald E. Brown, Research Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To determine the effect of water-reaction during the hypervelocity of impact and penetration of hypervelocity rods and shaped charge jets.

AN INVESTIGATION OF THE EFFECTS OF HYDRO-REACTION DURING HYPERVELOCITY IMPACT AND PENETRATION

Ronald E. Brown, Research Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To determine whether exothermic chemical energy released during the transit of hypervelocity, long-rod, aluminum penetrators through water and target impact is intense enough to contribute to terminal effectiveness. Innovative approaches for accelerating reaction will be emphasized. The work involves hypervelocity experimentation and analyses.

PHYSICS

FREE-ELECTRON-LASER AMPLIFIER AND OSCILLATOR SENSITIVITY TO VIBRATIONS AND DISTORTIONS

William B. Colson, Distinguished Professor

Joseph Blau, Research Associate Professor

Department of Physics

Sponsor: Joint Technology Office for High Energy Lasers

OBJECTIVE: To determine the sensitivity of free electron laser (FEL) amplifiers and oscillators to vibrations and distortions.

SUMMARY: Developed 4D FEL simulations to run on cluster computers, compared to other codes, and existing FEL experiments; developed new start-to-end analysis of FEL systems; studied new FEL weapon system designs; and established tolerances for system vibrations and electron beam quality.

PRESENTATIONS:

Blau, J., Colson, W.B., Edmonson, R., Neuerman, R., Cohn, K., and Stanton, M., "Electron Beam Quality and Stability Effects in FEL Amplifiers and Oscillators," 31st International FEL Conference, Liverpool, United Kingdom, August 2009.

Edmonson, R.L., Blau, J., Colson, W.B., Neuerman, R.A., Cohn, K., and Stanton, M., "Stability Effects in FEL Amplifiers and Oscillators," 12th Annual Directed Energy Symposium, San Antonio, Texas, November 2009.

THESES DIRECTED:

Edmonson, R.L., "Free Electron Laser Stability Effects and Design of an Electrostatic Cathode Test Cell," Master's Thesis, Naval Postgraduate School, December 2009.

Neuerman, R.A., "Simulation and Design Methods for Free Electron Laser Systems," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: High Power Lasers, Free Electron Lasers, Directed Energy

THE FREE ELECTRON LASER PROGRAM

William B. Colson, Distinguished Professor

Department of Physics

Sponsor: Raytheon Company

OBJECTIVE: The Navy is interested in the design, development, fabrication, integration, and test of a 100-kw-class free electron laser (FEL) device that can be used to demonstrate the scalability of the necessary FEL physics and engineering for an eventual megawatt (MW)-class FEL device.

Raytheon and the Naval Postgraduate School will collaborate on a preliminary design phase IA of the overall FEL program effort. Phase IA will result in a preliminary design of the 100-kw, scalable FEL system. A presentation of the system design at a preliminary design review will provide the Office of Naval Research with a proposal for the transition from a demonstrated (nominal) 10-kw FEL capability, currently at hand, to a 1.6 micron, near-infrared (NIR), weapon-class FEL via a 100-kw-class Innovative Navy Prototype phase. This 100-kw FEL is intended to provide the physics and engineering information needed to support MW-class FEL-device development. That MW-class FEL could be an element of a full-fledged weapon-system testbed, in a separate and subsequent contract action, that would include a beam director, beam control, and fire control elements for eventual introduction into the Fleet.

PHYSICS

THE FREE ELECTRON LASER PROGRAM

William B. Colson, Distinguished Professor

B. Rusnak, Research Associate Professor

Department of Physics

Sponsor: Raytheon Company

OBJECTIVE: In conjunction with Raytheon, the Naval Postgraduate School (NPS) will study and compile data on ship vibration, temperature, humidity, etc., as those variables affect sensitive equipment for accelerator technology.

Raytheon engineers and NPS faculty will conduct physics and engineering feasibility design on superconducting RF (SRF) and room temperature RF cavities that may be applicable for shipboard integration. Raytheon engineers and NPS faculty will conduct design studies to propose possible accelerator locations in current naval vessels, as well as Navy of the Future DDX and CGX. Raytheon collaborated with NPS faculty and will support the NPS studies with empirical knowledge and expertise gained from Raytheon's experience integrating state-of-the-art technology into naval vessels. NPS has studied design recommendations for ruggedized SRF or normal conducting cavity designs for future integration on Navy platforms.

KEYWORDS: Electric Ship, Free Electron Lasers, Railguns, Sonar, Radar, Propulsion, Power Systems

FREE ELECTRON LASER WEAPONS RESEARCH: A FOUR-DIMENSIONAL ANALYSIS OF FEL AMPLIFIERS AND OSCILLATORS

William B. Colson, Distinguished Professor

Department of Physics

Sponsor: Air Force Research Laboratory

OBJECTIVE: To develop modeling and simulation of operational, free-electron-laser directed-energy weapons using both amplifiers and oscillator configurations.

THE NAVAL POSTGRADUATE SCHOOL AND THE UMD THZ SOURCE DEVELOPMENT

William B. Colson, Distinguished Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: The Naval Postgraduate School Free Electron Laser Group will study the design of a THz source based on the free electron laser mechanism.

THE OFFICE OF NAVAL RESEARCH FREE ELECTRON LASER DEVELOPMENT PROGRAM AT THE NAVAL POSTGRADUATE SCHOOL

William B. Colson, Distinguished Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To support the Office of Naval Research in the development of free electron lasers using a combination of theoretical and experimental research.

OPERATIONAL POWER REQUIREMENTS ON NAVAL ELECTRIC SHIPS

William B. Colson, Distinguished Professor

Joseph Blau, Research Associate Professor

K. Cohn, Research Assistant Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: In collaboration with the Center for Electro-Mechanics at the University of Texas at Austin, this project supports the Office of Naval Research development of electric ships by modeling the different weapon systems and other vital components and evaluating their electric interaction on the power grid and with each other.

SUMMARY: Created computer models of the electrical systems of the free electron laser, railgun, sonar, propulsion, and radar; and determined the states of readiness of the free electron laser, the power requirements for each state, and how to transition between these states.

TECHNICAL REPORT:

Gattozzi, Cohn, K., Hebner, R., and Colson, W.B., "Operational Power Requirements on Naval Electric Ships," University of Texas at Austin Technical Report.

KEYWORDS: Electric Ship, Free Electron Lasers, Railguns, Sonar, Radar, Propulsion, Power Systems

RESEARCH SUPPORTING THE OFFICE OF NAVAL RESEARCH FREE ELECTRON LASER INNOVATIVE NAVY PROTOTYPE

William B. Colson, Distinguished Professor

Joseph Blau, Research Associate Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To support the Office of Naval Research (ONR) development of free electron lasers (FEL) using a combination of theoretical and experimental research.

SUMMARY: Several contributions were made to the ONR development of the FEL Innovative Navy Prototype under study by Raytheon and Boeing, as well as general contributions to the field of FELs. Both four-dimensional and three-dimensional FEL simulation codes have been improved in ways requested by industry and supporting their upcoming experimental projects. Naval Postgraduate School experimental-systems development is preparing cathode test cells for future evaluation of new cathodes. The Stanford thermionic injector has been operated, evaluated, and upgraded to make use of a photo-injector cathode.

CONFERENCE PUBLICATION:

Colson, W.B., Blau, J., Cohn, K., Jimenez, J., and Pifer, R., "Free Electron Lasers in 2009," *Proceedings of the 31st International FEL Conference*, Liverpool, United Kingdom, 2009 (<http://www.jacow.org>).

PRESENTATIONS:

Blau, J., Colson, W.B., Edmonson, R., Neuerman, R., Cohn, K., and Stanton, M., "Electron Beam Quality and Stability Effects in FEL Amplifiers and Oscillators," 31st International FEL Conference, Liverpool, United Kingdom, August 2009.

Edmonson, R.L., Blau, J., Colson, W.B., Neuerman, R.A., Cohn, K., and Stanton, M., "Stability Effects in FEL Amplifiers and Oscillators," 12th Annual Directed Energy Symposium, San Antonio, Texas, November 2009.

PHYSICS

THESES DIRECTED:

Edmonson, R.L., "Free Electron Laser Stability Effects and Design of an Electrostatic Cathode Test Cell," Master's Thesis, Naval Postgraduate School, December 2009.

Neuerman, R.A., "Simulation and Design Methods for Free Electron Laser Systems," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: High Power Lasers, Free Electron Lasers, Directed Energy

SIMULATION RESEARCH SUPPORTING THE OFFICE OF NAVAL RESEARCH FREE ELECTRON LASER INNOVATIVE NAVY PROTOTYPE

William B. Colson, Distinguished Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: This project supports the Office of Naval Research Free Electron Laser (FEL) INP by developing and contributing to end-to-end simulations of the 100kw FEL system scalable to MW levels.

HOSE SELECTION EXPERIMENTS

Bruce C. Denardo, Associate Professor

Department of Physics

Sponsor: Templeman Automation, L.L.C.

OBJECTIVE: To provide Templeman Automation personnel with access to oceanographic simulation facilities. To provide oversight and component testing during the HOSE selection experiments at the Naval Postgraduate School's flow tank.

QUASIPERIODIC MOTION

Bruce C. Denardo, Associate Professor

Department of Physics

Support: Naval Sea Systems Command

OBJECTIVE: Quasiperiodic motion in an oscillatory system is a permanent, non-steady motion that corresponds to a frequency that is irrationally related to the primary frequency. The most interesting occurrence of quasiperiodicity (QP) is in driven, damped, nonlinear systems. QP is often unwanted in practical systems (i.e., heavy rotating machinery), and an understanding of QP can lead to its avoidance. QP also produces sound which could be used for identification and tracking. In addition, the study of QP is part of the Naval Postgraduate School course PH4459 (Nonlinear Oscillations and Waves). Due to the importance of QP, the subject was recently split from chaos. However, much of the material of QP still needs to be established, including analytical calculations, computer simulations, and demonstrations. One purpose of this research is to help fill this need. The main objective of this thesis is to explore QP in the common case of nonlinear isotropic oscillators which have two identical orthogonal modes. One mode is driven and the other mode can be excited due to the nonlinear coupling between the modes. Experiments have shown that QP can occur in such systems.

SUMMARY: Extensive computer simulations of the standard model system did *not* yield QP. Except for an unusual form of QP, the motion settled into a steady state with constant amplitudes of the two modes. Further simulations showed that QP did not occur in several alternative model systems, including weakly anisotropic oscillators. However, weakly coupled nonlinear oscillators did exhibit QP. Suggestions were made on future research regarding how QP can be understood and predicted, and how the contradiction between theory and experiment may be resolved.

THESIS:

Triantafyllos, K., "Theoretical Investigations of Quasiperiodic Motion," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: Quasiperiodicity, Quasiperiodic Motion, Unsteady Motion

THE USE OF BUBBLES FOR PRESSURE MINE SWEEPING

Bruce C. Denardo, Associate Professor

Department of Physics

Support: Office of Naval Research

OBJECTIVE: When bubbles are introduced into water, a pressure drop in and below the bubble field is expected because the decrease in average density of the bubbly water causes a reduction of hydrostatic pressure. Pressure mines operate by monitoring for a pressure drop that is characteristic of that due to the Bernoulli Effect of a passing ship. If such a pressure drop is detected, the mine will detonate. The idea of this research project is to use bubbles to simulate the pressure drop due to a passing ship, in order to harmlessly detonate a pressure mine. One issue is the actual nature of the change in pressure due to a bubble field. Because the system is dynamic rather than static, hydrostatic calculations may be substantially inaccurate. The motion of the bubbles will induce an upward flow that is expected to contribute to the lowering of the pressure due to the hydrostatic effect. Calculations of this effect are very difficult, and can only be made with many approximations. Experimental investigations must therefore be undertaken.

SUMMARY: As part of phase one for this research, thesis student Jeffrey Murawski and the principal investigator conducted experiments in both the small flow tank in Halligan Hall and the tow tank in Spanagel Hall. The bubbler consisted of a system of porous tubes connected to a pressurized air source. In the flow tank, the bubbler was held fixed, and the pressure was measured at various points in, above, and beyond the bubble field. Pressure drops were detected. Rough scaling arguments suggest that the pressure drop for a much larger apparatus would be sufficient for pressure mine sweeping. As a more realistic test, the tow tank was then used; the tow tank is not only larger, but allows the bubbler to be moved through the water (rather than forcing water past the bubbler as in the flow tank). Good results were again obtained. Phase two of the project was consequently awarded by the Office of Naval Research. Phase two will involve the testing of different bubbler material and a substantially larger bubbler.

THESIS:

Murawski, J.J., "The Use of Bubbles for Pressure Minesweeping," Master's Thesis, Naval Postgraduate School, December 2009. (Surface Navy Association Award winner for Academic Excellence in Surface Warfare).

KEYWORDS: Bubbles, Pressure Mine Sweeping

WATER WAVE AND ACOUSTIC RADIATION FORCES

Bruce C. Denardo, Associate Professor

Department of Physics

Support: Naval Sea Systems Command

OBJECTIVE: The time-averaged force on a body due to a wave is referred to as a *radiation force*, which occurs because waves carry momentum. One purpose of this water wave research is to perform experiments to ascertain whether the theory is valid, and to publish the results. In this acoustics research, a small body is attracted to a high-intensity source of diverging sound waves as a result of radiation pressure. The goal is to perform an experiment to measure the force and to compare the values to the theory. A possible application is an ultrasonic purifier for fluids, where unwanted particles are attracted to a sound

source and collected electrostatically or by another means. Such a device could be used to replace centrifuges for oil on submarines.

SUMMARY: The water-wave experiment was successful, and the results were published. Measurements of the force agreed with the water wave theory even at large wave amplitudes. The water wave analog applies to side-by-side ships in a rough sea, and rough estimates show that the force of attraction of two ships can be substantial. Regarding the acoustics research, it was shown that the attraction of a body in a diverging sound field can be roughly understood and calculated as a time-averaged Bernoulli Effect. Rigorous scattering calculations in the literature yield a radiation force that is within a factor of two of the Bernoulli result. Applications of the phenomenon include ultrasonic filtration of liquids. Experiments were performed in an anechoic chamber with an aluminum ball suspended from an analytical balance. Good agreement between the radiation force theory and experimental data occurred when the drag on the ball due to the jetting from the hole was included in the theory. The importance of obtaining a spherical wave was shown by an analytical proof that a local spherical wave approximation is invalid for a general, axisymmetric diverging wave.

PUBLICATION:

Denardo, B.C., Puda, J.J., and Larraza, A., "A Water Wave Analog of the Casimir Effect," *American Journal of Physics*, **77**, 1095-1101, 2009.

THESES DIRECTED:

Bentivoglio, M. and Rochelle, J., "Measurements and Analysis of the Acoustic Radiation Force," Master's Thesis, Naval Postgraduate School, June 2009.

Oviatt, E. and Patsiaouras, K., "Acoustic Attraction," Master's Thesis, Naval Postgraduate School, December 2009. (Outstanding Thesis Award winners from the Naval Postgraduate School Department of Physics)

KEYWORDS: Radiation Pressure, Wave Pressure, Radiation Force

A SCALABLE NETWORK MONITORING PROGRAM

David K. Ford, Research Professor

Department of Physics

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: To provide technical support for the Defense Advanced Research Projects Agency Scalable Network Monitoring Program.

**COLLABORATIVE RESEARCH: TRANSPORT IMAGING OF
SEMICONDUCTOR NANOWIRES**

Nancy M. Haegel, Professor

Department of Physics

Sponsor: National Science Foundation

OBJECTIVE: To demonstrate direct imaging of charge transport in semiconductor nanowires. Specific goals include measurements as a function of nanowire diameter, measurement of contact resistance, and study of the role of catalysts on optical and transport uniformity.

THE DEVELOPMENT OF AN IMAGING TRANSPORT INSTRUMENT FOR MATERIALS RESEARCH AND EDUCATION

Nancy M. Haegel, Professor
Department of Physics

Sponsor: National Science Foundation

OBJECTIVE: An integrated transport system is proposed for optical imaging of transport phenomena – combining the power of imaging with the need for easy access to localized transport parameters. The instrument will make phenomena such as carrier diffusion and drift, charge injection at contacts, and transport in lower dimensional structures directly visible via the spatially resolved imaging of luminescence associated with charge recombination. It will offer capability for new experiments, provide integration with standard characterization techniques, and can be applied to a wide range of problems.

THE DEVELOPMENT OF AN IMAGING TRANSPORT INSTRUMENT FOR MATERIALS RESEARCH AND EDUCATION

Nancy M. Haegel, Professor
Department of Physics

Sponsor: National Science Foundation

SUMMARY: An integrated transport system has been developed that can perform optical imaging of charge transport phenomena – combining the power of imaging with the need for easy access to local transport parameters. Spatial resolution beyond the diffraction limit was obtained by using a near-field optical microscope internal to the scanning electron microscope. Measurement of minority carrier diffusion in solar cell materials and nanostructures was achieved. This project was completed in 2009.

PUBLICATIONS:

Haegel, N.M., Williams, S.E., Frenzen, C., and Scandrett, C., “Imaging Charge Transport and Dislocation Networks in Ordered GaInP,” *Physica B: Condensed Matter*, 404, 4963-4966, 2009.

Haegel, N.M., Mills, T.J., Talmadge, M., Scandrett, C., Frenzen, C., Yoon, H.J., et al., “Direct Imaging of Anisotropic Minority Carrier Diffusion in Ordered InGaP,” *Journal of Applied Physics*, 105, 023711, 2009.

THESES DIRECTED:

Baird, L., “Near Field Imaging of Gallium Nitride Nanowires for Characterization of Minority Carrier Diffusion,” Master’s Thesis, Naval Postgraduate School, December 2009.

Low, C.H., “Near Field Scanning Optical Microscopy (NSOM) of Nano Devices,” Master’s Thesis, Naval Postgraduate School, December 2008.

Williams, S., “A Study of the Correlation between Dislocations and Diffusion Length in InGaP Solar Cells,” Master’s Thesis, Naval Postgraduate School, December 2008.

KEYWORDS: Transport Imaging, NSOM, Near Field Optics, Nanoscale Resolution

PHYSICS

HIGH Z MATERIALS FOR NUCLEAR RADIATION DETECTION: SYNERGY OF GROWTH, CHARACTERIZATION, AND DEFECT PHYSICS FOR ROOM TEMPERATURE DEVICES

Nancy M. Haegel, Professor

Department of Physics

E.E. Haller, et al.

University of California-Berkeley

Sponsor: National Science Foundation, Department of Homeland Security

OBJECTIVE: To develop new “high Z” materials for room-temperature nuclear-radiation detectors. These detectors must be able to absorb a significant fraction of high-energy radiation, but must also be thin to be able to be manufactured and utilized in large quantity. This collaborative effort with the University of California-Berkeley will investigate new Bi-containing complex-oxide materials for this application. The Naval Postgraduate School contribution is to characterize the transport properties of these new materials.

PUBLICATION:

Haegel, N.M., Williams, S.E., Frenzen, C.L., and Scandrett, C., “Minority Carrier Lifetime Variations Associated with Misfit Dislocation Networks in Heteroepitaxial GaInP,” *Semiconductor Science and Technology*, December 2009 (submitted).

PRESENTATION:

Catalano, S.L. and Haegel, N.M., “Imaging Transport for the Determination of the Mobility-Lifetime ($\mu\tau$) Product in Nuclear Radiation Detector Materials,” poster presented at the 2nd Annual ARI Grantees Conference, Washington, D.C., April 2009.

THESES DIRECTED:

Catalano, S., “Transport Imaging: Developing an Optical Technique to Characterize Bulk Semiconductor Materials for Next-Generation Radiation Detectors,” Master’s Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Transport Imaging, Nuclear Radiation Detectors, Complex Oxides

IFFF/VMIFF AT COBRA GOLD

Nancy M. Haegel, Professor

Department of Physics

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To develop novel IR polymer emitters for IIFF and associated applications in the short-wavelength IR-part of the spectrum.

THE NAVAL POSTGRADUATE SCHOOL’S NEXT-GENERATION, VEHICLE-MOUNTED, IDENTIFICATION: FRIEND OR FOE, AND COBRA GOLD 2010

DEMONSTRATION/EVALUATION

Nancy M. Haegel, Professor

Department of Physics

Sponsor: Office of the Secretary of Defense (RRTO)

OBJECTIVE: To develop a next-generation device that offers a low-cost solution for the mitigation of air-to-ground fratricide by leveraging existing targeting and ranging systems. The device will employ a triggered emitter, which will provide an immediate warning signal in both thermal and near-IR bands if a vehicle is targeted by friendly forces. Three prototype devices will be designed, demonstrated, and evaluated in collaboration with the Marine Corps Experimentation Center of MARFORPAC, at Cobra Gold 2010.

PHYSICS

THESES DIRECTED:

Burnett, K., "Low Temperature Transient Performance of a Polymer Light-Emitting Diode," Master's Thesis, Naval Postgraduate School, June 2010.

Rose, E., "Generation of a Mid-Wave Infrared Signature using Microradiating Devices for Vehicle-Mounted Identification Friend or Foe Applications," Master's Thesis, Naval Postgraduate School, June 2009.

Woolsey, A., "Short Wave Infrared Emission using Erbium Doped Phosphors," Master's Thesis, Naval Postgraduate School, June 2010.

KEYWORDS: IFF, Fratricide Mitigation, Thermal Emitter, Close Air Support

NEAR-FIELD TRANSPORT IMAGING OF NANOWIRES

Nancy M. Haegel, Professor

Department of Physics

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: Near-field transport imaging will be applied to nanowire structures in collaboration with Defense Advanced Research Projects Agency (DARPA)-supported programs at NIST Boulder, the Georgia Institute of Technology, Magnolia Optical, and organizations developing nanowire materials for sensing and energy harvesting applications. The principal investigator will travel to the institutions listed above to present the unique Naval Postgraduate School (NPS) capability in transport imaging and to establish collaborations. The materials of interest include GaN and ZnO nanowires. Measurements will be made at NPS to provide characterization of minority-carrier diffusion length on samples provided by the collaborators.

THESES DIRECTED:

Ong, C.P., "Measurement of Minority Charge Carrier Diffusion Length in Gallium Nitride Nanowires using Electron Beam Induced Current," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: Nanowires, Transport Imaging, Near-Field Scanning Optical Microscopy, Minority Carrier Diffusion, GaN, ZnO

NEXT-GENERATION, REMOTELY TRIGGERED, PLED EMITTERS FOR IIFF FOR SPECIAL OPERATIONS FORCES

Nancy M. Haegel, Professor

Department of Physics

Sponsor: U.S. Special Operations Command, OSD Technology Transition Initiative

OBJECTIVE: To produce the next-generation individual identification friend or foe (IIFF) patch for mitigation of shooter-on-shooter fratricide. This work is done in conjunction with Add-Vision, Inc. These devices will be designed to be lighter and brighter than previous generations and will be part of the Technology Transition Initiatives from the Office of Secretary of Defense in FY09. One-hundred devices will be produced in Spiral 1, with field testing and evaluation planned for summer 2009.

PUBLICATIONS/PRESENTATIONS:

Numerous internal briefs and critical design reviews.

THESES DIRECTED:

Burnett, K., "Low Temperature Transient Performance of a Polymer Light-Emitting Diode," Master's Thesis, Naval Postgraduate School, June 2010.

Elmore, J., "Transient Effects of Polymer-Organic Light Emitting Diodes and their Impact on Individual Identification Friend/Foe," Master's Thesis, Naval Postgraduate School, December 2008.

Gardner, S., "Visible-to-SWIR Downconversion and Its Application to Individual Identification Friend or Foe," Master's Thesis, Naval Postgraduate School, June 2009.

Rose, E., "Generation of a Mid-Wave Infrared Signature using Microradiating Devices for Vehicle-Mounted Identification Friend or Foe Applications," Master's Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: IFF, Polymer Emitting Devices, Fratricide Mitigation

REMOTELY TRIGGERED, SHORT-WAVELENGTH INFRARED EMITTERS FOR INDIVIDUAL IDENTIFICATION FRIEND OR FOE AND RELATED APPLICATIONS

Nancy M. Haegel, Professor

Department of Physics

Sponsor: U.S. Special Operations Command

OBJECTIVE: To demonstrate prototype short-wavelength infrared (SWIR) emitters for individual identification friend or foe (IIFF) and related applications. Down-conversion materials will be utilized to convert visible PLED emission to the short-wavelength IR, creating a low-cost covert-triggered emitter.

THESES DIRECTED:

Gardner, S., "Visible-to-SWIR Downconversion and Its Application to Individual Identification Friend or Foe," Master's Thesis, Naval Postgraduate School, June 2009.

Woolsey, A., "Short Wave Infrared Emission using Erbium Doped Phosphors," Master's Thesis, Naval Postgraduate School, June 2010.

KEYWORDS: Fratricide Mitigation, Short Wavelength Infrared, SWIR, Upconversion, Phosphor

SMART, LIGHTWEIGHT, IR POLYMER EMITTERS FOR INDIVIDUAL (IIFF) AND VEHICLE (VMIFF) IDENTIFY FRIEND OR FOE AT COBRA GOLD

Nancy M. Haegel, Professor

Department of Physics

Sponsor: Office of the Secretary of Defense

SUMMARY: Novel, lightweight, and low-cost devices for remote identification have been developed using polymer-based light-emitting diodes (PLED). The emission is only visible through night-vision devices and only activates when targeted by friendly forces. A near-IR vehicle-mounted version (VMIFF) has also been demonstrated, using existing coding on targeting lasers for the Cobra platform and/or the ground laser target designator operated by the forward air controller. Both the IIFF and the VMIFF technology were demonstrated and tested at Cobra Gold 08. This extension of the program allowed for additional briefings (JFCOM and MCCDC) and a preliminary demonstration-of-principle for extending the technology to the thermal part of the spectrum.

PRESENTATIONS:

Numerous briefs to various Marine Corps and joint offices.

THESES DIRECTED:

Elmore, J., "Transient Effects of Polymer-Organic Light Emitting Diodes and their Impact on Individual Identification Friend/Foe," Master's Thesis, Naval Postgraduate School, December 2008.

Rose, E., "Generation of a Mid-Wave Infrared Signature using Microradiating Devices for Vehicle-Mounted Identification Friend or Foe Applications," Master's Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Vehicle Mounted Identification Friend or Foe, VMIFF, Triggered IFF, Air to Ground Fratricide Mitigation

TRANSPORT IMAGING OF SEMICONDUCTOR NANOWIRES

Nancy M. Haegel, Professor

Department of Physics

R. Maboudian

University of California-Berkeley

Sponsor: National Science Foundation

OBJECTIVE: To demonstrate direct imaging of charge transport in semiconductor nanowires using a unique method of near-field collection of luminescence associated with carrier recombination. A near-field optical scanning microscope (NSOM) will be operated inside an SEM to collect the distribution of luminescence from point source generation at the nanometer scale. The initial focus will be on transport in SiC films and wires and doped Si nanostructures.

PUBLICATIONS:

Baird, L., Ang, G.H., Low, C.H., Haegel, N.M., Talin, A.A., Li, Q., and Wang, G.T., "Imaging Minority Carrier Diffusion in GaN Nanowires using Near Field Optical Microscopy," *Physica B: Condensed Matter*, 404, 4933-4936, 2009.

Haegel, N.M., Low, C.H., Baird, L., and Ang, G.H., "Transport Imaging with Near-Field Scanning Microscopy," *Scanning Microscopy 2009*, SPIE Vol. 7378, 78732B, 2009.

Haegel, N.M., Williams, S.E., Frenzen, C.L., and Scandrett, C., "Minority Carrier Lifetime Variations Associated with Misfit Dislocation Networks in Heteroepitaxial GaInP," *Semiconductor Science and Technology*, December 2009 (submitted).

THESES DIRECTED:

Baird, L., "Near Field Imaging of Gallium Nitride Nanowires for Characterization of Minority Carrier Diffusion," Master's Thesis, Naval Postgraduate School, December 2009.

Low, C.H., "Near Field Scanning Optical Microscopy (NSOM) of Nano Devices," Master's Thesis, Naval Postgraduate School, December 2008.

Ong, C.P., "Measurement of Minority Charge Carrier Diffusion Length in Gallium Nitride Nanowires using Electron Beam Induced Current," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: Transport Imaging, NSOM, Near Field Optics, Nanoscale Resolution, SiC

AUTONOMOUS, AMPHIBIOUS ROBOTS FOR SURF ZONE OPERATIONS

Richard M. Harkins, Senior Lecturer

Department of Physics

Ravi Vaidyanathan, Assistant Professor

Department of Systems Engineering

Sponsor: Temasek Defense Systems Institute

OBJECTIVE: The Naval Postgraduate School (NPS), in conjunction with Case Western Reserve and Bristol Universities, began a two-year robotics and systems development program to address critical topics in the field of autonomous amphibious vehicles. This is a two-year funded program.

In recent years there has been significant interest in the development of robots capable of autonomous operation within turbulent-ocean surf-zone environments. This region, also referred to as the near-shore zone, encompasses the area between the outermost breakers and the bore area where wave water rushes onto the beach. The water in this locale is shallow, sometimes between 5 and 10 m deep; consequently, most waves there are unstable and extremely challenging for navigation and maintenance of stability. Areas within this region can be submerged during high tide and open during low tide, therefore demanding the capacity for locomotion in both regimes. Potential utilities for such a robot include mine clearing, terrain mapping, and scouting potential approach lanes for amphibious naval operations. Shallow water mines, in particular, are a very significant hazard that necessitates robotic operation through land and water in this expanse.

Although no mature examples of autonomous robots capable of operation in land and water exist today, many animals have developed singular modes of locomotion that are efficient in both terrestrial and aquatic substrates. For example, the preferred form of locomotion for crabs and lobsters is crawling, yet they maneuver smoothly both in and out of the water utilizing their appendages. There is a clear need for a methodology enabling the design and fabrication of vehicles with some fraction of this capacity. Such a vehicle could be a robot capable of the following mission sequence: 1) deployment offshore from an underwater or aerial venue (e.g., from an aircraft or submarine); 2) crawling underwater or swimming to a target zone (e.g., an area arrayed with shallow-water mines); 3) locomoting successfully over land and underwater obstacles to reach critical areas (e.g., areas with submerged or buried explosives); and 4) transmitting critical data (visual, acoustic, chemical, electronic, etc.) from its position to other vehicles and/or a remote operator. Ideally, the vehicle would be able to exit a given target zone aquatically or terrestrially to move to another region of interest.

Research in this program is driven by unresolved issues in this arena related to remote sensing, search and mapping, and mine countermeasures in the ocean littoral and/or rivers and streams. Specifically, this present work is aimed at addressing mobility and autonomous control issues in beach and ocean surf-zone regions. Challenges in this region include uneven substrates, rocks, boulder fields, shoals, wave surge, tidal currents, algal beds, etc. A robot operating in this region will be expected to navigate based on a specified compass heading, with GPS signals accessible while on land. Its controller must traverse terrain obstacles (large and small rocks, wet sand, etc.) without disrupting higher-level navigation sequences. Fundamentally, the design of such a vehicle must address the tradeoff between complex mechanical designs facilitating mobility over several substrates, versus the difficulty of controlling these structures with enough rigor for full autonomous operation.

In order to meet these demands, this research introduces a hybrid wheel-leg platform (dubbed WhegsTM) drawing inspiration from cockroach mobility principles. In past work, the laboratory tests, demonstrations, and field testing have shown intriguing potential for combining active and passive control mechanisms to achieve the autonomy and robustness necessary for operation in the rocky terrain, hard sand, and soft sand that characterize the surf zone environment.

SUMMARY: In the first year of this program, the principal investigators (PIs) reported the completion of the design and simulation of an autonomous amphibious robot, Pelican WhegsTM, capable of navigating the challenging terrain of the ocean surf-zone region based on abstracted biological inspiration. Abstracted biological inspiration attempts to distill salient biological principles and implement them using presently available technologies; its efficacy lies in the successful fusion of organic and inorganic architectures such that the proper level of influence of biology is established for optimum performance. Pelican WhegsTM benefits from insect-inspired mechanisms of locomotion for movement over challenging and different

terrains. Design innovations will allow the robot to navigate on rough terrain and underwater, and to accomplish tasks with little or no low-level control. Because of the ability of Pelican Whegs™ to swim, in future operations the robot could be deployed far out to sea, swim toward shore, and then walk along the ocean floor through the surf zone and onto the beach. It could search for objects on land or on the ocean floor and swim over obstacles that pose any risk of trapping it, making it ideal for mine sweeping, surveying, and civilian applications. The robot's mechanics are an integrated and essential part of its control system. It does not have, or need, sensors and control circuits to actively change its gait. Instead, its mechanics cause it to passively adapt its gait appropriately to very different terrains. Therefore, subsequent work in motor control circuits (in year two) will be reduced to controlling broad directives of the robot. The confluence of active and passive control mechanisms in the robot will ultimately result in a system with the simplicity of a wheeled vehicle that nevertheless facilitates the mobility of a legged vehicle. Prototype fabrication and control system implementation will be completed in year two of the research program.

PUBLICATION:

Boxerbaum, A., Dunbar, T., Bachmann, R.M., Harkins, R., Quinn, R.D., et al., "Design and Testing of a Highly Mobile Insect-Inspired Autonomous Robot in a Beach Environment," *International Journal of Design and Nature*, 2010 (to appear).

CONFERENCE PUBLICATION:

Boxerbaum, A., Klien, M., Quinn, R.M., Harkins, R., and Vaidyanathan, R., "Design of a Semi-Autonomous Amphibious Surf-Zone Robot," *IEEE/ASME Conference on Advanced Intelligent Mechatronics (AIM)*, pp. 974-979, Singapore, July 2009.

CONTRIBUTION TO BOOK:

Harkins, R., Dunbar, T., Boxerbaum, A.S., Bachmann, R.J., Quinn, R.D., Burgess, S.C., and Vaidyanathan, R., "Confluence of Active and Passive Control Mechanisms Enabling Autonomy and Terrain Adaptability for Robots in Variable Environments," (invited chapter), *IAENG Transactions on Electrical Engineering - Special Edition of the 2008 World Congress on Engineering and Computer Science*, C. Douglas, W. Grundfest, and L. Schruben (Eds.), 12 pp., IEEE Press (forthcoming).

THESIS DIRECTED:

Baravik, K., "Object Localization and Ranging using Stereo Vision for Use on Autonomous Ground Vehicles," Master's Thesis, Naval Postgraduate School, June 2009.

DYNAMIC COMPRESSION OF WEAPONS MATERIALS

Robert S. Hixson, Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: To conduct research to measure the dynamic response of materials of interest in weapons applications. This work will involve both theory and experiment. Experimental research involves acquiring fundamental physics data on dynamic compression of materials that have application to the performance of various classes of weapons. Work will be guided by the needs of the conventional weapons community; these needs will be derived from discussions with appropriate researchers and from written Department of Defense requirements.

PHYSICS

AN INVESTIGATION OF NEW KINDS OF ARMOR

Robert S. Hixson, Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: Development of new and advanced armor concepts continues to be a need. This includes the development of both personnel and vehicle armor. The principal investigators (PIs) have begun working to develop new armor concepts using very fundamental, shock-compression physics ideas.

SUMMARY: The principal investigators (PIs) have chosen to look at two physical mechanisms to make initial improvements to armor systems. Since the impact of a projectile or fragment onto a material causes shock waves to be generated, the goal was to modify the nature of these waves to minimize the chances of target damage. This was done in two ways. First, the PIs looked at ways to cause the shock wave to spread laterally very quickly as it propagates through the armor material. This was best done by using orthotropic materials; that is, materials that have a much slower wave speed in the through thickness than laterally. The PIs developed a layered system as the first attempt at calculationally creating such a material. Next, the PIs looked at using a porous material to absorb kinetic energy from the shock wave (particle velocity) and turn it into heat material. Very porous materials can do this very efficiently. The first material used was porous aluminum at a relatively small distention. The PIs will next look at porous polymers with considerable distention.

THESES DIRECTED:

Boey, C.W., "Investigation of Shock Wave Attenuation in Porous Materials," Master's Thesis, Naval Postgraduate School, December 2009.

Ho, C.-C., "Assembly and Commissioning of Naval Postgraduate School Gas Gun for Impact Studies," Master's Thesis, Naval Postgraduate School, December 2009.

Ong, C.W., "Investigation of Advanced Personnel Armor using Layered Construction," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: Shock Compression, Porous, Damage, Armor

ACOUSTIC DETECTION OF ULTRA-HIGH-ENERGY COSMIC-RAY NEUTRINOS

Daphne Kapolka, Senior Lecturer

Department of Physics

Sponsor: Stanford University

OBJECTIVE: The Naval Postgraduate School will provide services in support of Stanford University's project studying the possibility of detecting ultra-high neutrinos from cosmic rays using acoustic techniques.

AUTOMATED DETECTION OF A TARGET OF INTEREST

Daphne Kapolka, Senior Lecturer

Department of Physics

Sponsor: OPNAV N87

OBJECTIVE: To examine a signal of interest to the Office of Naval Intelligence (ONI) and build an automated detection algorithm to alert operators to its presence.

SUMMARY: The signal for this project is classified. However, the automated detector was programmed and tested against detections validated by the ONI's acoustic analysts to determine the probability-of-detection versus false alarm rates. Careful consideration was made of the trade-offs in frequency and time

resolution and in the thresholds used. The results on this transient have been encouraging enough to justify further development by the Johns Hopkins University Applied Physics Lab for possible incorporation in future sonar-processing builds.

THESIS DIRECTED:

Welch, S., "Investigation of Submarine Transient Signal and Automated Detection Algorithm Development (U)," Master's Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Automated Detection, Passive Sonar, Tonals

AUTOMATED PASSIVE DETECTION OF PASSING CONTACTS

Daphne Kapolka, Senior Lecturer

Department of Physics

Sponsor: Naval Sea Systems Command-05

OBJECTIVE: To program an automated detection algorithm that can successfully discriminate loud noises displaying a Doppler shift and return range and velocity.

SUMMARY: Signals of passing aircraft were collected. Jet aircraft signatures were broadband with minimal tonal structure, whereas propeller planes exhibited clear Doppler shifts on one or more tonals as they passed the closest point of approach (CPA). The automated detection algorithm was based on finding the time where the signal, having exceeded a given threshold, had its peak amplitude. The slope of strongest tonal's frequency versus time plot at CPA was used as a starting point in the detection algorithm. The cross-correlation between the observed time-frequency plot and a synthetic time-frequency plot was calculated to detect the presence, velocity, and range of propeller planes automatically.

THESIS DIRECTED:

How, W.K., "Automated Detection of a Crossing Target Based on Its Doppler Shift," Master's Thesis, Naval Postgraduate School, March 2009.

KEYWORDS: Automated Detection, Doppler Shift, Passive Acoustics

VECTOR SENSOR BEAMFORMING

Daphne Kapolka, Senior Lecturer

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To examine the benefits and problems involved with using acoustic vector sensors in arrays.

SUMMARY: Acoustic vector sensors measure particle velocity in addition to pressure. A typical configuration will include one omnidirectional pressure sensor and three orthogonal particle velocity sensors. Two in-air Microflown vector sensors were placed in a linear array about a conventional microphone. To eliminate the necessity of calibration, transfer functions between the channels were established. Beamforming was conducted in the frequency domain. The array showed a clear ability to resolve the typical right-left bearing ambiguity inherent in linear arrays of omnidirectional pressure sensors. Follow-on work is planned to extend the in-air work to underwater applications using Wilcoxon vector sensors.

THESIS DIRECTED:

Caulk, J., "Experimental and Theoretical Performance of a Particle Velocity Sensor in a Hybrid Acoustic Beamformer," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: Vector Sensor, Beamforming, Particle Velocity

A MEMS-BASED MINIATURE MICROPHONE FOR DIRECTIONAL SOUND SENSING

Gamani Karunasiri, Associate Professor

Jose O. Sinibaldi, Research Associate Professor

Department of Physics

Sponsor: National Science Foundation

SUMMARY: To develop a MEMS-based, miniature, directional sound sensor for potential applications of next-generation smart sensors. The proposed research program is academically rich and highly interdisciplinary between physics, biology, and electrical and mechanical engineering, combining the advantageous properties of biological systems with mature silicon-based MEMS technology.

The successful completion of the research program will have substantial pay-offs since these sensors can be utilized as the building blocks for the development of an intelligent sensor network. The long-term goal of the research is to develop sensor arrays tailored to applications in micro air-vehicles for pinpointing explosions and aligning imaging systems in the direction of incoming threats by monitoring the direction of sound. In addition, a network of these sensors can be used for unattended movement monitoring. Other applications include directional sensitive hearing aids, which can provide high-quality hearing by reducing the unwanted signals. The graduate students will acquire hands-on expertise in this multidisciplinary research. In addition to graduate students, the Naval Postgraduate School will provide research opportunities for promising local high school students. The plan is to involve them in the proposed research to enhance their science and engineering skills. The findings of the research will be published in refereed scientific journals and presented in national and international conferences devoted specifically to this multidisciplinary area of research.

A MEMS-BASED MINIATURE MICROPHONE FOR DIRECTIONAL SOUND SENSING

Gamani Karunasiri, Associate Professor

Jose O. Sinibaldi, Research Associate Professor

Department of Physics

Sponsor: National Science Foundation

OBJECTIVE: To develop an integrated MEMS-based miniature-microphone system for directional sensing of sound similar to that of the *Ormia ochracea* fly. The fly employs a unique coupled-mechanical-bar system to extract the direction of sound with ears separated only about 500 μm . A set of such sensors can be used for pinpointing explosions by monitoring the direction of sound which can be deployed using micro air-vehicles. In addition, a network of these sensors can be used for unattended movement monitoring.

THESES DIRECTED:

Harrison, S., "Free Field Modeling of a MEMS-Based Pressure Gradient Microphone," Master's Thesis, Naval Postgraduate School, December 2009.

Muamad, N., "Characterization of MEMS of Directional Microphone with Solid and Perforated Wings," Master's Thesis, Naval Postgraduate School, June 2009.

Simsek, K., "Developing a Capacitance Readout Circuitry for a Directional MEMS Sound Sensor and Sound Source Localization in a Sensor Network Environment," Master's Thesis, Naval Postgraduate School, June 2009.

KEYWORDS: Directional Sound Sensor, Micro-Electro-Mechanical-Systems

REAL-TIME THZ DETECTION USING A MICROBOLOMETER FOCAL PLANE ARRAY

Gamani Karunasiri, Associate Professor

Department of Physics

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To develop a real-time terahertz-imaging system using microbolometer focal-array technology originally developed for infrared imaging in the 8-12 μm band. The detection of THz radiation is typically done using either antenna-coupled semiconductor detectors or superconducting bolometers. The imaging of objects using these detection schemes either requires complex scanning mechanisms that slow down the data acquisition or expensive cryogenic cooling, which limits the widespread use. The successful conclusion of the research project will lead to the incorporation of microbolometer technology for real-time imaging in THz frequencies. Such imaging systems can be used in standoff detection of concealed objects and medical imaging with deeper penetration.

REAL-TIME THZ DETECTION USING A MICROBOLOMETER FOCAL PLANE ARRAY

Gamani Karunasiri, Associate Professor

Department of Physics

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To develop a real-time terahertz imaging system using microbolometer focal array technology originally developed for infrared imaging in the 8-12 μm band. The successful conclusion of the research project will lead to the incorporation of microbolometer technology for real-time imaging at THz frequencies. Such imaging systems can be utilized in stand-off detection of concealed objects and medical imaging with deeper penetration compared to infrared thermography.

THESES DIRECTED:

Freeman, W., "THz Quantum Cascade Laser," Ph.D. Dissertation, Naval Postgraduate School, June 2009.

Liao, P.-Y., "Designing and Simulating a Terahertz Sensor using Finite Element Modeling," Master's Thesis, Naval Postgraduate School, December 2009.

KEYWORDS: Terahertz, Microbolometer, Spectroscopy

THE NAVAL SEA SYSTEMS COMMAND – THESES AND CURRICULUM SUPPORT

Andres Larraza, Associate Professor

Department of Physics

Sponsor: Naval Sea Systems Command

OBJECTIVE: To provide direct support between curriculum sponsor (COMNAVSEASYS COM), curriculum students, faculty, and their research. The proposed funding is provided for sponsorship of the Naval Postgraduate School Combat Systems Science and Technology (CSS&T) curriculum. Participants will work directly with the faculty in the study of missile systems, as well as student thesis research. This curriculum includes topics that are of direct interest and have application to the Naval Sea Systems Command (NAVSEA), including theater air missile defense, radar missile design, advanced sensors, and improvements to better prepare the student in future air and surface threats.

SUMMARY: NAVSEA recognizes the need to participate directly with the faculty in the study of military systems and in curriculum development, educational upgrades, and student thesis research. NAVSEA also recognizes the importance of directly linking the curriculum students to the programs managed by

NAVSEA. Central funding at the (physics) department level is requested in order to enable better coordination with individual research projects and to initiate efforts that further the science and technology goals of NAVSEA in the following areas:

- 1) Open Architecture. An important aspect of the system integration efforts is that of open architecture. Under the capstone course Advance Applied Physics Laboratory, PC401, students will learn system requirements and system integration modeled after the open architecture protocols established by PEO IWS.
- 2) Atmospheric propagations of high-power laser beams. One of the most significant problems facing the delivery of energy on target for DEW is the atmospheric variability. Development of course material (even a full course) will be undertaken to address these technical issues.
- 3) Total Ship Systems Engineering (TSSE). Revisit the TSSE track of the CSS&T curriculum in order to increase participation in the design project that incorporated combat systems integration.

CURRICULUM RESEARCH AND THESIS ACTIVITIES:

1) Development of techniques for neutralizing explosive threats; 2) directed-energy weapons concepts; 3) THz source and detector development for IDE detection and imaging; 4) advanced methods in radar imaging; 5) imaging transport instrument for material research; 6) field experiments on IIFFs; 7) cyber security; 8) development on new IR/optics technologies; 9) counter-DEW technologies; 10) new weapons concepts systems onboard electric ships (including railgun and FEL); and 11) new sonar technologies, including vector sensor technologies.

A THz MICROMAGNETRON
Andres Larraza, Associate Professor
Department of Physics
Sponsor: National Science Foundation

OBJECTIVE: To investigate and develop MEMS-based reverse-magnetron designs as sources of THz radiation, for applications on improvised explosive device (IED) detection. Because terahertz radiation can penetrate paper and clothes, it can be used as means to detect terror material in envelopes and packages and can become useful for airport security.

SUMMARY: There is a need for more readily available intense sources of THz radiation for imaging and other applications, especially in the area of IED detection. Most current sources of THz radiation are either very dim (e.g., nonlinear down-conversion of optical lasers generate typically nW outputs), inefficient, or both (e.g., far-IR lasers have output in the THz region of few mW, but efficiencies of about .01%). Unfortunately, the intense sources are uniformly bulky and difficult to transport (e.g., free electron laser and synchrotron radiation sources). This research focuses on a new magnetron MEMS-based design, where the anode is located at the center of the magnetron, surrounded by a cathode ring. In this case, electrons move radially inward in the combined electric and magnetic cross-fields and can reach orbiting angular frequencies in the THz region, even with a field of the order of 1 T.

A THz source consisting of several hundred reverse magnetrons in a 1cm × 1cm chip was designed. The integration of the chip in a confocal cavity provides feedback among the reverse magnetrons. Once integration is finally accomplished—chip, chip mount, magnet, cavity, electric power, and heat management—the device is expected to occupy a volume equal to about two soda cans. This will make the design portable and bright, which is a highly desirable condition for field applications.

PRESENTATIONS:

Larraza, A., “Overtly Seeing the Covertly: A THz Reverse Micromagnetron,” NMCR Technology Fair, Washington, D.C., December 2009.

Larraza, A., “A THz Micromagnetron,” NMCR Semi Annual Technical Review, May 2009.

PATENT APPLICATION:

Larrazza, A., Catterlin, J., and Wolfe, D., “THz Reverse Micromagnetron,” Provisional Patent Number 61/248,301, September 2009.

KEYWORDS: THz Sources, Magnetron, MEMS

DC ELECTRON BEAM SOURCE UPGRADE AND OPERATION

John W. Lewellen, Research Associate Professor

Department of Physics

Sponsor: Office of Naval Research

SUMMARY: The electron beam source from the Stanford Superconducting Accelerator (SCA-DC gun) was successfully converted to operate as a photoinjector. This included not only adaptation of the beamline and control system to incorporate a Class IV Nd:YAG frequency quadrupled drive laser, but also extensive modifications to the gun’s 300 kV power system.

The photocathode conversion allows us to use a laser to gate electron emission from the cathode. By controlling the amplitude, spot size, and position of the laser spot on the cathode, the principal investigators (PIs) can “map” the relative efficiency of the cathode as an electron emitter as a function of position. The more uniform the emission, all else being equal, the higher the quality of the electron beam that can be generated.

Initial operation of the system was a success, with a “first-beam” event in April 2009.

The PIs also significantly upgraded the high-voltage power system to incorporate many additional diagnostics and capabilities. Traditionally, in a DC electron gun such as the SCA, “floating” the cathode (in this case, at -300 kV) is required to allow the remainder of the accelerator to be at ground. However, this can make implementing diagnostics and controls for the cathode region difficult. The PIs implemented a – to their knowledge – unique solution to this problem. A conventional, modular, uninterruptable power supply (UPS) providing 110VAC is floated as part of the high-voltage stack assembly. Therefore, many off-the-shelf instruments, such as power supplies, oscilloscopes, grid pulsers, and such, can be incorporated at high voltage in an autonomous fashion without requiring a high-voltage standoff transformer. A fiber-optic Ethernet link to the stack allows communication with the HV stack instrumentation without any HV-specific restrictions. The use of this framework allows great flexibility in modifying the instrumentation and measurement package. Current run lifetime of the battery pack is approximately six hours, and can be fully recharged overnight. The runtime can be extended easily, or more instrumentation accounted for, simply by adding another battery module.

The point of this modification is to greatly enhance the measurements of what is happening at the “business end” of the gun when the photocathode drive laser hits the cathode. For instance, using this instrument package, it can be determined whether electrons are emitted from the cathode proper, from a cathode grid (if any), or from the cathode focusing cone. Comparison of these measurements with downstream charge measurements allows us to determine whether the electron beam is scraping within the gun. These capabilities, plus the drive laser capabilities, allow us to perform detailed mapping of the cathode emission surface and subsequent beam transport as a function of charge density, emission location, vacuum history, and cathode regeneration cycle. This allows us to profile the performance of potential next-generation cathodes such as dispenser photocathodes, which offer the promise of high quantum efficiencies (electrons out per photons striking the cathode) and the ability to replenish the QE *in situ* after an extended period of operation.

The PIs are presently engaged in applying this same technique to a stand-alone cathode test cell, to allow us to perform these measurements more easily and with less risk of damage to the SCA injector gun.

Field Emitter Beam Source Design. Next-generation field emitter cathodes, such as diamond pyramid and carbon nanoflake-based cathodes, are also promising sources for future high-power accelerators, but much additional information is needed about their ability to operate at high currents for extended periods of time. To that end, the PIs have finished the design and are presently working on the construction of a field-emitter cathode test stand. Unlike the dispenser photocathodes, the high-voltage portion of the test cell is relatively simple. However, to test large-area FE cathodes, the electric field should be uniform over the

emission area. Thus, considerable time and effort was expended in designing the cathode-anode region to assure a flat-field over the area of interest.

One of the major problems encountered during field emitter cathode testing, historically, has been the very high current densities from the emitter tips, melting or ablating the anode used in the testing. The solution is to move the anode further from the cathode; however, this results in the need for a much higher voltage, as the FE cathodes have minimum required electric field gradients of $\sim 10 - 20$ MV/m (depending on the cathode) to turn on. Thus, the test cell has to meet several somewhat perpendicular criteria: good field flatness, large cathode-anode spacing, good imaging capabilities, and fine adjustability.

As of the end of CY09, the design was at the 90% complete level and the PIs were preparing for a final design review (now completed, as of this writing) before performing final assembly.

Superconducting Injector. The world's first quarter-wave cavity based superconducting RF injector operated twice during 2009. During the first run, a gap voltage of ~ 250 kV was achieved. During the second run, which incorporated cavity processing and conditioning techniques, a gap voltage of ~ 700 kV was achieved.

The quarter-wave gun design offers several significant potential benefits over conventional electron gun design. These include compactness for a given RF frequency; high gradients at the cathode for improved emission control and transport; ready adaptability to a number of power feed options; simplicity; and cavity geometry robustness and stability. These features make it of very great interest to the Navy's high-power directed-energy efforts. To that end the development cycle was accelerated, with the injector progressing from design concept to completed prototype in approximately one year. This represents, in fact, a record for SRF gun development worldwide.

To be useful for the Navy's DE programs, a next-generation injector must meet several critical performance targets. In particular, the single-bunch beam quality must be good, and must be linearly scalable over a range of bunch charges up to 1.5 nC, and beam currents of >100 mA must be possible. The first QW gun prototype is intended to explore high-charge bunch formation, acceleration, transport, and quality, but at modest (10 mA) beam currents. The intent is to validate the basic physics design; capability for high-current operation will be incorporated into the second prototype.

NPS and Niowave, the gun's manufacturer, have collaborated with Boeing on the design and construction of a 1-kHz drive laser for the QW gun, to be used for the beam formation testing. The post-gun electron beam transport line and diagnostics, to be used to measure the bunch properties, is essentially complete. The transport line was designed in collaboration with MIT, Boeing and Niowave, and has been constructed at the Niowave source test facility in Lansing, Michigan.

MW-CLASS FREE-ELECTRON-LASER INJECTOR TECHNOLOGY VALIDATION

John W. Lewellen, Research Associate Professor

Department of Physics

Sponsor: Joint Technology Office-High Energy Lasers

OBJECTIVE: To test and evaluate new, promising cathode technology in several high-power electron injectors, and to test new merge designs with several high-power electron injectors for free electron lasers.

A SUPERCONDUCTING ACCELERATOR AND BEAMLINE TRANSPORT SYSTEM FOR THE NAVAL POSTGRADUATE SCHOOL FREE ELECTRON LASER: EXPERIMENTAL STUDIES OF FREE ELECTRON LASERS IN NAVAL ENVIRONMENTS

John W. Lewellen, Research Associate Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: The Naval Postgraduate School (NPS) is initiating an experimental program in free electron lasers (FEL) and particle accelerator physics. This research will directly support the development of shipboard self-defense directed-energy weapons systems by conducting experiments intended to study the effects of shipboard environments on FEL operations.

PHYSICS

INNOVATIVE RESEARCH IN RAILGUN TECHNOLOGY

William B. Maier, Senior Lecturer and Chair

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To make significant innovative contributions to the Navy's Railgun Program, while educating military officers in railgun technology through thesis research. Specifically, research in FY08 is focused on improved rail life, barrel design, and railgun power supplies having low-voltage energy storage.

RAILGUN TECHNOLOGY

William B. Maier, Senior Lecturer and Chair

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To develop and improve railgun technology.

CLASSIFIED SERVICES

Richard C. Olsen, Professor

Department of Physics

Sponsor: Defense Intelligence Agency

OBJECTIVE: To support the Defense Intelligence Agency.

DEVELOPMENT OF MASINT TECHNOLOGIES

Richard C. Olsen, Professor

Department of Physics

Sponsor: Defense Intelligence Agency

OBJECTIVE: The Naval Postgraduate School (NPS) will assist the Defense Intelligence Agency in the development of MASINT technologies. NPS personnel will act under the direction of Mr. Art Zuehlke, DIA/DT. Research in nonconventional remote-sensing techniques (non-imaging) will be studied.

GROUND SYSTEMS SUPPORT (IPA)

Richard C. Olsen, Professor

Department of Physics

Sponsor: Secretary of the Air Force

OBJECTIVE: To support work in the area of ground systems for military satellite systems.

MAPPING URBAN MATERIALS USING SPECTROMETRY AND LIDAR

Richard C. Olsen, Professor

Department of Physics

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To study the use of imaging spectrometry and LIDAR systems for the mapping of urban materials and structures.

PHYSICS

THE MASINT OUTREACH/LIAISON PROJECT

Richard C. Olsen, Professor

Department of Physics

Sponsor: Defense Intelligence Agency

OBJECTIVE: To support the Defense Intelligence Agency. The Naval Postgraduate School MASINT Chair will support the Defense Intelligence Agency in spectral and polarimetric imaging.

MOUNTAIN SNOW COVER, ALBEDO, AND SPACE-TIME INTERPOLATION FROM MULTISPECTRAL SENSORS

Richard C. Olsen, Professor

Department of Physics

Sponsor: National Geospatial-Intelligence Agency

OBJECTIVE: To support the spectral research efforts at the National Geospatial-Intelligence Agency.

REMOTE SENSING CENTER DEVELOPMENT AND SUPPORT

Richard C. Olsen, Professor

Department of Physics

Sponsor: Naval Postgraduate School

OBJECTIVE: The development and operation of the Remote Sensing Center.

REMOTE SENSING RESEARCH

Richard C. Olsen, Professor

Department of Physics

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To support the work of the Office of the Secretary of Defense Capabilities Office in the areas of remote sensing and the application of social network analysis to technology problems.

REMOTE SENSING RESEARCH IN SUPPORT OF THE OFFICE OF THE SECRETARY OF DEFENSE

Richard C. Olsen, Professor

Department of Physics

Sponsor: Office of the Secretary of Defense

SUMMARY: The Remote Sensing Center at the Naval Postgraduate School will support the Office of the Secretary of Defense with research in the areas of counter-narcotics, unmanned aerial vehicles (UAVs), and irregular warfare. Ms. Zayas will be required to interface with senior officials within the Defense Department, State Department, homeland defense, law enforcement agencies, and intelligence organizations to identify and develop new capabilities to satisfy urgent needs in the areas of special operations, homeland security, asymmetric warfare, counter-insurgency, and others, as required. Routine interaction with flag officers and senior executives will occur frequently. Subject matter expertise in the area of special technical operations and RF technologies shall be maintained. Industrial and government laboratory technology surveys will be conducted to facilitate the incorporation of emerging technologies into advanced capabilities.

PHYSICS

REMOTE SENSING RESEARCH IN SUPPORT OF THE OFFICE OF THE SECRETARY OF DEFENSE SPECIAL CAPABILITIES OFFICE

Richard C. Olsen, Professor

Department of Physics

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To support the work of the Office of the Secretary of Defense Special Capabilities Office in the areas of counter-narcotics, unmanned aerial vehicles, and irregular warfare.

SNOW COVER RESEARCH WITH MULTISPECTRAL SENSORS

Richard C. Olsen, Professor

Department of Physics

Sponsor: National Geospatial-Intelligence Agency

OBJECTIVE: To support the spectral research efforts at the National Geospatial-Intelligence Agency. The application is to use sub-pixel spectral techniques to exploit large-area-coverage spectral sensors for the mapping of snow and ice. The work is being jointly conducted with Dr. Jeff Dozier (UCSC) and Dr. Tom Painter (University of Utah).

SPECIAL CAPABILITIES SUPPORT TO THE OFFICE OF THE SECRETARY OF DEFENSE

Richard C. Olsen, Professor

Department of Physics

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To support the Office of the Secretary of Defense in the appointment of Mr. Brian Hibbeln as the Assistant Deputy Undersecretary of Defense for Special Capabilities. In this role, Mr. Hibblen will serve as directed by Mr. Kubricky, in his role as the Deputy Undersecretary of Defense, Advanced Systems and Concepts.

SPECIAL TEST PLANNING AND GROUND SUPPORT

Richard C. Olsen, Professor

Department of Physics

Sponsor: National Signatures Program

OBJECTIVE: To conduct research in spectral imaging technology in support of the government. Data analysis from space and airborne sensors will be performed. Ground support will be provided in support of calibration efforts and ground truth efforts. Observations of ground targets will be analyzed for purposes of terrain classification and other military and intelligence purposes. Spectral analysis algorithms will be tested for applicability.

SPECTRAL ANALYSIS FOR A NATIONAL SIGNATURES PROGRAM

Richard C. Olsen, Professor

Department of Physics

Sponsor: National Signatures Program

OBJECTIVE: To support the spectral research efforts at the National Signatures Program Office.

PHYSICS

SPECTRAL AND POLARIMETRIC ANALYSIS FOR THE NATIONAL SIGNATURE PROGRAM

**Richard C. Olsen, Professor
Department of Physics**

Sponsor: National Signatures Program

OBJECTIVE: To support the spectral and polarimetric research effort at the National Signatures Program Office.

SPECTRAL TEST PLANNING AND GROUND TRUTH SUPPORT

**Richard C. Olsen, Professor
Department of Physics**

Sponsor: National Geospatial-Intelligence Agency

OBJECTIVE: To support the spectral effort at the National Geospatial-Intelligence Agency.

SUPPORT TO THE OFFICE OF SPECIAL CAPABILITIES

**Richard C. Olsen, Professor
Department of Physics**

Sponsor: Office of the Secretary of Defense

OBJECTIVE: NPS will support the Office of the Secretary of Defense.

TRACKING AND DETECTION WITH NON-IMAGING SYSTEMS

**Richard C. Olsen, Professor
Department of Physics**

Sponsor: National Geospatial-Intelligence Agency

OBJECTIVE: To exploit non-imaging systems for target detection and tracking. Non-imaging systems are nominally those with low-spatial resolution; resolution which is not sufficient to resolve targets. Targets in this case are typically vehicles, ships, or aircraft. Non-imaging systems generally have relatively high frame rates, and can provide long temporal sequences of observations. This research will apply technologies developed for the analysis of video systems to the non-imaging systems of interest. Existing technologies, as applied to video systems, depend to some extent on the ability to resolve targets (multiple pixels); the objective here is to move beyond that limitation.

THE SEAWEB ANTI-SUBMARINE NETWORK

**Joseph Rice, Research Professor
Department of Physics**

Sponsor: Office of Naval Research, 321MS

OBJECTIVE: To develop state-of-the-art, through-water acoustic communication, navigation, and networking technology for application to future anti-submarine warfare (ASW), with emphasis on distributed, underwater sensor systems.

SUMMARY: Two tasks were performed in 2009: NGAS and Seastar. NGAS involved the Naval Postgraduate School (NPS) in the NATO Next-Generation Autonomous Systems (NGAS) Joint Research Project (JRP). A JRP agreement was signed in 2009 by NURC, Canada, Norway, and the United States Office of Naval Research. The JRP calls for the U.S. to provide Seaweb networking for interoperable through-water communications amongst heterogeneous ASW sensor nodes being developed by the participating nations. An initial capability was successfully exercised in May 2009 involving four U.S. and four Norwegian sensor nodes operating against a cooperative Italian submarine.

PHYSICS

Seastar performed systems analysis, simulations, and design tradeoff studies for a Seastar undersea local-area network (LAN) that links a set of peripheral sensors through high-bandwidth acoustic links to a Seaweb-compatible centralized node for beamforming and data fusion. Candidate Seastar network protocols were tested at the Unet 2007 trial (in conjunction with AUVFest 2007 in Panama City, Florida) using six Seaweb modems. In 2008, this project designed a Seastar modem for short-range (500-m), high-bandwidth (20 kHz) operation and awarded a contract for fabrication of six prototype units. In 2009, NPS took delivery of these modem prototypes.

PUBLICATIONS:

Kerstens, B., Ziomek, L., and Rice, J., "Selection of an Optimum Carrier Frequency and Bandwidth Comparisons of MFSK and OFDM Underwater Acoustic Signals," *IEEE Journal of Selected Areas in Communication* (submitted).

Otnes, R., Birkeland, R., Kj  ll, J., Rice, J., Creber, R., Fletcher, C., et al., "NGAS09 Sea Trials, Taranto, Italy, May 2009," FFI 2009/01637, 28 October 2009.

PRESENTATION:

Rice, J., "Seaweb ASW Network and NGAS'09," Office of Naval Research Maritime Sensing Review, Monterey, California, 18-20 August 2009.

THESES DIRECTED:

How, W.K., "Automated Detection of a Crossing Contact Based on its Doppler Shift," Master's Thesis, Naval Postgraduate School, March 2009.

Thompson, S., "Displacement of Tethered Hydro-Acoustic Modems by Uniform Horizontal Currents," Master's Thesis, Naval Postgraduate School, December 2009.

Thompson, S., "Sound Propagation Considerations for a Deep Ocean Acoustic Network," Master's Thesis, Naval Postgraduate School, December 2009.

THE SEAWEB MARITIME NETWORK

Joseph Rice, Research Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To develop state-of-the-art, through-water, acoustic communication, navigation, and networking technology for application to future anti-submarine warfare involving undersea, distributed-networked systems, with emphasis on deployable, autonomous-distributed systems.

THE SEAWEB MARITIME NETWORK

Joseph Rice, Research Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To develop technology for through-water digital communications enabling Naval special warfare applications, including near-real-time telemetry of in situ maritime-surveillance contact reports.

SUMMARY: In 2009, this project addressed a U.S. Special Operations Command requirement for self-organization of a deployed underwater sensor network. This project developed a network discovery process that enables a field of spontaneously deployed, ad hoc underwater nodes to auto-configure network routes.

PHYSICS

The process is initialized as nodes in the network are discovered, link distances measured, and optimal routes chosen from among candidate routes according to comparative evaluation of a cost function. The implemented network discovery process was tested with computer simulation and demonstrated at sea with a network of 19 nodes. The resultant network routes obtained upon completion of the ad hoc network-discovery process are comparable to those derived from Dijkstra's algorithm. It is concluded that the network discovery process always produces a shortest-path route from a master node to each discovered node in the network. Sensitivity analysis on the route cost evaluation function was performed. The capability was handed off to the Sea Eagle ACTD for a September 2009 USSOCOM technical demonstration.

PUBLICATIONS:

Blue, P.M., Fletcher, C., and Rice, J., "Simulation of Seaweb Link and Network Layers using OPNET," *The Technical Cooperation Program Annual Meeting on ASW Systems and Technology*, Halifax, Nova Scotia, Canada, 21-25 September 2009.

Rice, J., Ong, C.W., Pinelli, R., and Coryer, M., "A Discovery Process for Initializing Ad Hoc Underwater Acoustic Networks," *The Technical Cooperation Program Annual Meeting on ASW Systems and Technology*, Halifax, Nova Scotia, Canada, 21-25 September 2009.

PRESENTATION:

Rice, J., "Seaweb Maritime Network," AUVSI/ONR Unmanned Systems Technology Review, Orlando, Florida, 9-12 February 2009

THESES DIRECTED:

Ong, C.-W., "A Discovery Process for Initializing Ad Hoc Underwater Acoustic Networks," Master's Thesis, Naval Postgraduate School.

Zinkhon, D., "Undersea Node Localization using Node-to-Node Acoustic Ranges in a Distributed Seaweb Network," Master's Thesis, Naval Postgraduate School, March 2009.

SEAWEB PORT SURVEILLANCE

Joseph Rice, Research Professor

Department of Physics

Sponsor: Office of the Assistant Secretary of Defense

OBJECTIVE: To adapt U.S. Navy Seaweb technology involving commercial telesonar modems, digital acoustic through-water communications, and open-systems interface (OSI) networking, configure two oceanographic current sensor nodes for moored deployment on a shifting seabed, obtain periodic (every 10 minutes) measurements of current profiles (i.e., current vector as a function of water depth) in a major maritime port environment characterized by strong currents, include up to seven telesonar repeater nodes deployed on the seabed as part of the Seaweb network linking the sensor nodes with a gateway node, outfit an operational U.S. Coast Guard navigation buoy as a radio/acoustic communications (Racom) gateway node, use a cellular telephone modem for communications between the gateway node and an ashore server, advance the Seaweb capability for automated ad hoc discovery and initialization of network routes, provide near-real-time data dissemination via an internet web site, advance technologies and methods with applicability at other maritime locales for the purpose of serving a broad user community (scientific, environmental, commerce, academic, security, and emergency response, e.g., oil spills, sewage spills, etc.)

SUMMARY: The SF Bayweb 2009 experiment was conducted through a collaboration led by the Naval Postgraduate School, Monterey, California. The following organizations are participating in SF Bayweb 2009: SPAWAR Systems Center Pacific, San Diego, California; U.S. Coast Guard, 11th District, Yerba Buena, California; SFSU Romberg Tiburon Center for Environmental Studies, Tiburon, California;

University of California-Berkeley, Berkeley, California; Central and Northern California Ocean Observing System (CeNCOOS), Moss Landing, California; Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, California; and University of California-Davis Bodega Marine Lab, Bodega, California.

Long-term Seaweb testing made use of the Racom gateway buoy, permitting engineers to exercise the network from remote locations, including SPAWAR Systems Center Pacific (San Diego, California) and Teledyne Benthos, Inc. (Falmouth, Massachusetts). Hence, the SF Bayweb experiments provided critical testing that circumvented problems at those more significant Naval demonstrations.

Acoustic Communications. Testing characterized the Raccoon Strait acoustic conditions as noisy and variable. Future operations requiring a convenient location with adverse acoustic conditions would do well to return to this test site. Installation of the U.S. Navy Racom kit onto an operational U.S. Coast Guard buoy was successful. The gateway provided reliable communications between the underwater network and an AirLink cellular telephone modem. Remote access to the gateway node was via an IP address. Two ADCP sensors were deployed on a near-seabed StableMoor buoy. They were deployed in each of the two Bayweb experiments. While the deployments were tricky, boat handling and rigging procedures were refined such that the installation of these unique sensors became routine. The sensors successfully measured current vectors as a function of depth. Although these data were not telemetered in near-real-time, the data were internally recorded.

PUBLICATIONS:

Ramp, S., Rice, J., Stacey, M., Garfield, T., and Largier, J., "SF Bayweb 2009: Planting the Seeds of an Observing System in the San Francisco Bay," *MTS/IEEE Oceans Conference*, Biloxi, Mississippi, 26-29 October 2009.

Rice, J. and Ramp, S., "San Francisco Bayweb 2009," *ACM SenSys Workshop on Under-Water Networking*, Berkeley, California, 3 November 2009.

PRESENTATION:

Ramp, S., Rice, J., Stacey, M., Williams, M., Largier, J., Garfield, T., and Bahr, F., "SF Bayweb 2009, Planting the Seeds of a New Observing System in the San Francisco Bay," Eastern Pacific Ocean Conference, Victoria, British Columbia, Canada, 23-26 September 2009.

UNET COALITION INTEROPERABILITY

Joseph Rice, Research Professor

Department of Physics

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To cooperatively advance the development of undersea communication, navigation, and networking technology; to extend network-enabled concepts to Naval and autonomous maritime systems; to foster undersea-warfare connectivity and interoperability across systems, platforms, missions, and nations; and to identify measures for transmission security and communication security.

SUMMARY: This coalition warfare project contributed to and benefited from the TTCP MAR TP-9 Undersea networking (Unet) key technical area (KTA). The Unet KTA staged three major S&T experiments: two in Canada and one in the U.S. The Unet KTA convened 14 technical workshops and pioneered the establishment of standards and the advancement of technology. Principal investigator Joseph Rice is Chair of the International TTCP Unet Collaboration.

PUBLICATION:

Rice, J., *TTCP Unet Collaborative Work Plan*, September 2009.

PRESENTATION:

Rice, J., "Unet Undersea Networking," The Technical Cooperation Program Annual Meeting on ASW Systems and Technology, Halifax, Nova Scotia, Canada, 21-25 September 2009.

ALGAE-BASED BIO-DIESEL FUELS

Jose O. Sinibaldi, Research Associate Professor

Department of Physics

Knox T. Millsaps, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Office of Naval Research

OBJECTIVE: This project involves the study and selection of algae strands that can grow from farmland waste and be farmed to produce large quantities of bio-diesel fuel for non-combatant vehicles. A BAA will be awarded as a subcontract. The project at the Naval Postgraduate School examines the current testing standards for diesel fuels and establishes the relevance of such testing standards to bio-derived diesel fuels. There is a need for more detailed kinetics information for bio-diesel fuels to allow exploration of issues in engine and fuel design. Flame studies can provide overall chemical kinetic information that is currently lacking in the literature for bio-diesel fuels. An experimental apparatus to measure laminar flame speeds will be designed and implemented to convey overall chemical reaction rate information.

BLAST RESISTANCE RESEARCH FOR MILITARY VEHICLES

Jose O. Sinibaldi, Research Associate Professor

Department of Physics

Sponsor: Office of Naval Research

SUMMARY: The Office of Naval Research (ONR) supports a Multidisciplinary University Research Initiative (MURI) on "an integrated cellular materials approach to force protection." The research has two key aspects. One is concerned with designs and basic understanding of the response of ceramic/metal/organic systems that defeat ballistic threats at lower weight than conventional designs. The other is concerned with cellular material concepts for defeating blast-generated impulses caused by buried explosives. The main purpose of the proposed experiments is to provide high-fidelity measurements of the dynamic parameters required for calibration and development of a numerical code that can be used for simulating the response of panels to glass bead blasts. In addition, testing against EFPs and SC jets will be performed in years two and three. In addition, the Naval Postgraduate School's light gas gun will be utilized in year three to experimentally determine proper sand EOSs under these dynamical situations.

COLLABORATIVE RESEARCH ON BLAST-RESISTANT STRUCTURES FOR MILITARY VEHICLES – IN COLLABORATION WITH THE UCSB AND UVA (LEAD) MURI PROGRAM

Jose O. Sinibaldi, Research Associate Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To collaborate with the Office of Naval Research MURI team on force protection; and to provide high-fidelity measurements of the dynamic parameters required for calibration and development of a numerical code that can be used for simulating the response of panels to soil blasts. Initial experiments will determine both the shape and velocity of the soil front and the ejecta thickness. This research will comprehensively characterize the blast wave, thereby calibrating and validating the dispersion aspects the Deshpande, et al., constitutive law used for the soil. The pendulum will not be used; instead, the high-speed camera will record soil-wave profiles as they exit the blast chamber. Characterization of the blast wave will also serve to fine-tune the details of detonation, such as camera trigger timing and detonator placement. A second set of experiments will be comprised of soil blast impacts upon metal and composite plates mounted onto the pendulum, and these will utilize the full instrumentation package. Peak loads and transferred

momenta will be recorded by the Kolsky bars and pendulum displacement, respectively. In addition, the dynamic deformation of the back faces will be recorded with the high-speed camera using the shadow moire technique. The responses of these panels to soil impact will be used to fully-calibrate and validate the Deshpande, et al., Dynamic Soil Compaction Model. They will also be used to explore momentum transfer incorporating the fluid-structure-interaction.

PERFORMANCE TESTING OF SOLUBLE NANOCATALYSTS IN TACTICAL PROPULSION SYSTEMS

Jose O. Sinibaldi, Research Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To investigate the practical performance increase of tactical propulsion systems with the use soluble nano-catalysts in high-performance fuels, such as JP-10.

ACOUSTIC IMMERSION AND THREE-DIMENSIONAL PROPAGATION STUDIES EMPLOYING ACOUSTIC VECTOR SENSORS IN SHALLOW WATER

Kevin B. Smith, Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To study the three-dimensional response of the acoustic vector field in the presence of environmental variability and noise, and to analyze acoustic inversion techniques for environmental properties using meta-heuristic approaches and properties of the complex intensity field.

ACOUSTIC INVERSION AND THREE-DIMENSIONAL STUDIES EMPLOYING ACOUSTIC VECTOR SENSORS IN SHALLOW WATER

Kevin B. Smith, Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To study the three-dimensional response of the acoustic vector field in the presence of environmental variability and noise; and the analysis of acoustic inversion techniques for environmental properties using meta-heuristic approaches and properties of the complex intensity field.

SUMMARY: For one element of this work, a computational model of underwater acoustic propagation was expanded to include the full 3D environment and propagation physics. This model was then employed to explore features of the 3D acoustic vector field in the presence of environmental variability. Specifically, the shallow water variability introduced by non-linear internal waves was explored in collaboration with Georges Dossot, a graduate student at the University of Rhode Island pursuing a Ph.D. in Ocean Engineering. The results showed good agreement with observations of the influence of such non-linear internal waves on acoustic mode coupling.

Concurrent with this work, additional studies with the 2D version were pursued in the development of general inversion schemes (e.g., for localization, geoacoustic parameter inversions, etc.) in collaboration with Steve Crocker at NUWC-NPT, who is pursuing a Ph.D. in Ocean Engineering at the University of Rhode Island. Exploitable features of the complex acoustic intensity field were also examined for inversion of attenuation parameters in the environment. The emphasis of the inversions was geoacoustic parameter inversions, due to the emphasis on shallow-water propagation, and source localization.

In addition, some collaborative work was done with researchers in the Netherlands on noise generated from wind turbines. The 2D version of the model was adapted to account for long-range propagation in the air over a water boundary.

PUBLICATION:

Verheijen, E., Jabben, J., Schreurs, E., and Smith, K.B., "Impact of Wind Turbine Noise in the Netherlands," *Noise Control Engineering Journal*, 2009 (submitted).

PRESENTATIONS:

Clark, C.A. and Smith, K.B., "Full Spectrum Acoustic Wave Propagation Prediction," *Journal of the Acoustical Society of America*, 125, pp. 2704, 2009.

Crocker, S.E., Miller, J.H., Smith, K.B., Hines, P.C., and Osler, J.C., "Geoacoustic Inversion using Specific Acoustic Impedance," *Journal of the Acoustical Society of America*, 126, pp. 2234, 2009.

Dossot, G.A., Miller, J.H., Potty, G.R., Lynch, J.F., Lin, Y.-T., Newhall, A.E., et al., "Modeling Intensity Fluctuations of Acoustic Transmissions from the Research Vessel Sharp during Shallow Water 2006," *Journal of the Acoustical Society of America*, 126, pp. 2304, 2009.

KEYWORDS: Acoustic Vector Field, Particle Velocity, Acoustic Intensity, Vector Sensors, Geoacoustic Inversion

THE ENGINEERING ACOUSTIC RESEARCH AND EDUCATION VISITING PROFESSORSHIP AT THE NAVAL UNDERSEA WARFARE CENTER-NEWPORT

Kevin B. Smith, Professor

Department of Physics

Sponsor: Naval Undersea Warfare Center-Newport Division

OBJECTIVE: To establish an Engineering Acoustic Research and Education Visiting Professorship in the Sensors and Sonar Systems Department at the Naval Undersea Warfare Center-Newport Division (NUWC DIVNPT); and to outline responsibilities for supporting the position.

TECHNICAL CHALLENGE SUPPORT FOR VECTOR SENSOR ARRAY DEVELOPMENT

Kevin B. Smith, Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To assist the Office of Naval Research, Code 321MS, in the development and coordination of technical efforts to investigate the performance of the latest generation of acoustic vector sensors under a variety of environmental conditions, sensor configurations, and array construction designs. Additional specific objectives of this work include the development of analytical and numerical models of the acoustic vector field in the near- to far-field transition region for a wide range of frequencies. This includes characterization of the scattered acoustic vector field from canonical objects, which may lead to improvements in the understanding of flow noise fields in towed arrays.

SUMMARY: This work was done in close collaboration with colleagues at NUWC-NPT, principally CAPT (USNR) Bob Barton, who is also pursuing a Ph.D. degree in Ocean Engineering at the University of Rhode Island. In this work, the principal investigator (PI) was involved in discussions with NUWC-NPT regarding their plans for upgrading their calibration facility for calibrating vector sensors, and the PI provided suggestions for improvement. The PI also interacted with the NUWC-NPT group working on the Progeny sensors under IWS5, and provided some theoretical explanations for features observed in their calibration data. In addition, the PI organized and hosted a vector sensor BAA planning meeting in March 2009 at the Naval Postgraduate School (NPS).

In the study of fundamental features of the scattered vector field, CAPT Barton and the PI developed generalized descriptions of the total vector intensity field (incident plus scattered) in the near- to far-field transition regions for a range of objects. Analytical expressions were derived for solid (both rigid and fluid-

filled) spheroids and elastic spherical shells. Numerical results were computed for solid objects in the resonance region over a range of material properties.

The results of the scattering work indicated the existence of unique features in the complex intensity components. These features were further analyzed and qualitatively described by their respective characteristic impedance relative to the surrounding fluid (assumed sea water). Experimental data was collected in the NPS Department of Physics anechoic chamber, and preliminary analysis of that data shows very good agreement with predictions.

Prior to initiating the experimental work, some in-air vector sensors (on loan from the Dutch company Microflow) were obtained and put through rigorous calibration studies in the anechoic chamber. The results of this work were the basis for an NPS Master's thesis.

PUBLICATION:

Barton, R.J. and Smith, K.B., "A Characterization of Scattered Acoustic Intensity Vector Fields of Rigid and Fluid Filled Spheroids in the Resonance Region," *Journal of Underwater Acoustics*, 2009 (submitted).

HESIS DIRECTED:

Caulk, J., "Experimental and Theoretical Performance of a Particle Velocity Vector Sensor in a Hybrid Acoustic Beam Former," Master's Thesis, Naval Postgraduate School, December 2009 (co-advisor).

KEYWORDS: Shallow Water Acoustics, Vector Sensors

A CONCEPT FOR A DEEP-WATER UNDERSEA ACOUSTIC NETWORK

LT Scott R. Thompson, USN, NPS Student

Department of Physics

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To examine the deep Seaweb concept, whereby U.S. Navy Seaweb technology would be employed in ocean basins by exploiting the ocean's deep sound channel to communicate across large, horizontal distances.

THE MEMS ACOUSTIC SENSOR

LCDR Mike Touse, USN, Student

Department of Physics

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To design, fabricate, package, and test a micro-electromechanical directional microphone.

DEPARTMENT OF PHYSICS

**2009
Faculty Publications
and Presentations**

JOURNALS

Baird, L., Ang, G.H., Low, C.H., Haegel, N.M., Talin, A.A., Li, Q., and Wang, G.T., "Imaging Minority Carrier Diffusion in GaN Nanowires using Near Field Optical Microscopy," *Physica B: Condensed Matter*, 404, 4933-4936, 2009.

Bill, R., Felts, J., Fant, B., Krier, H., Glumac, N., Brown, R., and Sinibaldi, J.O., "An Experimental Study of the Reaction of Aluminum and Water in Underwater Shaped Charges," *JANNAF Journal of Propulsion and Energetics*, Vol. 2, April 2009.

Caporaso, G., Chen, Y., Sampayan, S., Akana, G., Anaya, R., Anderson, D., et al., "Dielectric Wall Accelerators for Proton Therapy," *Medical Physics*, Vol. 36, Iss. 6, p. 2691, 2009.

Cheney, M. and Borden, B., "Imaging Moving Targets from Scattered Waves," *Inverse Problems*, 25, 123005, 2009 (invited topical review).

Clark, C.A. and Smith, K.B., "Full Spectrum Acoustic Wave Propagation Prediction," *Journal of the Acoustical Society of America*, 125, pp. 2704, 2009.

Crocker, S.E., Miller, J.H., Smith, K.B., Hines, P.C., and Osler, J.C., "Geoacoustic Inversion using Specific Acoustic Impedance," *Journal of the Acoustical Society of America*, 126, pp. 2234, 2009.

Denardo, B.C., Puda, J.J., and Larraza, A., "A Water Wave Analog of the Casimir Effect," *American Journal of Physics*, Vol. 77, pp. 1095-1101, 2009.

Dossot, G.A., Miller, J.H., Potty, G.R., Lynch, J.F., Lin, Y.-T., Newhall, A.E., et al., "Modeling Intensity Fluctuations of Acoustic Transmissions from the Research Vessel *Sharp* during Shallow Water 2006," *Journal of the Acoustical Society of America*, 126, pp. 2304, 2009.

Freeman, W. and Karunasiri, G., "Monte Carlo Simulation of Terahertz Step Well Quantum Cascade Laser Structures," *SPIE*, 73110V, 2009.

Grbovic, D. and Karunasiri, G., "Fabrication of Bi-Material MEMS Detector Arrays for THz Imaging," *SPIE*, 731108, 2009.

Haegel, N.M., Williams, S.E., Frenzen, C., and Scandrett, C., "Imaging Charge Transport and Dislocation Networks in Ordered GaInP," *Physica B: Condensed Matter*, 404, 4963-4966, 2009.

Haegel, N.M., Mills, T.J., Talmadge, M., Scandrett, C., Frenzen, C., Yoon, H.J., et al., "Direct Imaging of Anisotropic Minority Carrier Diffusion in Ordered InGaP," *Journal of Applied Physics*, 105, 023711, 2009.

Hayes, D.B., Gray, G.T., and Hixson, R.S., "U-6Nb Shear Stress Relaxation in Compression Waves," *International Journal of Plasticity*, 25 #4, pp. 635-648, 2009.

Larraza, A., "A THz Micromagnetron," *NMCR Semi Annual Technical Review*, May 2009.

Li, Y., Chemerisov, S., and Lewellen, J., "Laser Pulse Shaping for Generating Uniform Three-Dimensional Ellipsoidal Electron Beams," *Physical Review Special Topics – Accelerators and Beams*, 12, 020702, 2009.

Rigg, P.A., Greeff, C.W., Knudsen, M.D., and Hixson, R.S., "Influence of Impurities on the Alpha to Omega Phase Transition in Zirconium under Dynamic Loading Conditions," *Journal of Applied Physics*, 106 #12, Article #123532, 2009.

Santos, R., Alves, F., Taranti, C., de Amorim Filho, J., and Karunasiri, G., "Quantum Well Infrared Photodetectors: Design using the Transfer Matrix Method," *SPIE*, 7298, 72980B, 2009.

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Sinibaldi, J.O., "Development of a Lab-Scale Buried Explosive Simulator," *ONR MURI Review on Cellular Structures for Military Armor Applications*, Massachusetts Institute of Technology, Cambridge, Massachusetts, April 2009.

"Direct Measurements of the Alpha-Epsilon Transition Stress and Kinetics for Shocked Iron," *Journal of Applied Physics*, 105 #10, Article 103502, 2009.

CONFERENCE PUBLICATIONS

Blau, J., Colson, W.B., Edmonson, R., Neuerman, R., Cohn, K., and Stanton, M., "Electron Beam Quality and Stability Effects in FEL Amplifiers and Oscillators," *31st International FEL Conference*, Liverpool, United Kingdom, August 2009.

Blue, P.M., Fletcher, C., and Rice, J., "Simulation of Seaweb Link and Network Layers using OPNET," *The Technical Cooperation Program Annual Meeting on ASW Systems and Technology*, Halifax, Nova Scotia, Canada, 21-25 September 2009.

Brophy, C. and Sinibaldi, J.O., "Ignition and Initiation Improvements for Hydrocarbon/Air Mixtures in PDE Applications," *ONR Advanced Propulsion Mid-Year Review*, December 2009.

Catalano, S.L. and Haegel, N.M., "Imaging Transport for the Determination of the Mobility-Lifetime ($\mu\tau$) Product in Nuclear Radiation Detector Materials," *2nd Annual ARI Grantees Conference*, Washington, D.C., April 2009.

Cheney, M., Wang, L., and Borden, B., "Spatial, Temporal, and Spectral Aspects of Radar Data," *IEEE RadarCon09*, Pasadena, California, 4-8 May 2009.

Colson, W.B., Blau, J., Cohn, K., Jimenez, J., and Pifer, R., "Free Electron Lasers in 2009," *Proceedings of the 31st International FEL Conference*, Liverpool, United Kingdom, 2009 (<http://www.jacow.org>).

Edmonson, R.L., Blau, J., Colson, W.B., Neuerman, R.A., Cohn, K., and Stanton, M., "Stability Effects in FEL Amplifiers and Oscillators," *12th Annual Directed Energy Symposium*, San Antonio, Texas, November 2009.

Grbovic, D. and Karunasiri, G., "Fabrication of MEMS Bimaterial Sensors for Uncooled THz Imaging," *American Physical Society March Meeting*, Pittsburgh, Pennsylvania, March 2009.

Haegel, N.M., Low, C.H., Baird, L., and Ang, G.H., "Transport Imaging with Near-Field Scanning Microscopy," *Scanning Microscopy 2009*, SPIE Vol. 7378, 78732B, 2009.

Harris, J.R., Poole, B., Blackfield, D., and Chen, Y.-J., "Space Charge Waves, Mismatch, and Halo," *Workshop on Research Opportunities at UMER*, University of Maryland, 16 October 2009.

Harris, J.R., Hickman, B., Anaya, R., Cook, E.G., Hawkins, S., Holmes, C., et al., "Plasma Cathode for a Short-Pulse Dielectric Wall Accelerator," *IEEE Transactions on Plasma Science*, 37, 1069-1077, 2009.

Ho, I. and Sinibaldi, J., "Determination of Practical Computational Cell Size for Simulation of H₂ Air Detonations in Pulse Detonation Engines," *48th AIAA Aerospace Sciences Meeting*, AIAA-2010-957, Orlando, Florida, 4-7 January 2010.

Karunasiri, G., "Photodetectors from Ultraviolet to Terahertz," *10th Symposium on Application of Optoelectronics in Defence*, San Paulo, Brazil, 30 September–2 October 2009 (invited).

Larrazza, A., "Overtly Seeing the Covertly: A THz Reverse Micromagnetron," *NMCR Technology Fair*, Washington, D.C., December 2009.

PHYSICS

Otnes, R., Birkeland, R., Kj  ll, J., Rice, J., Creber, R., Fletcher, C., et al., “NGAS09 Sea Trials, Taranto, Italy, May 2009,” FFI 2009/01637, 28 October 2009.

Oviatt, E., Patsiaouras, K., and Denardo, B., “Acoustic Attraction,” *Meeting of the California Section of the American Physical Society*, Naval Postgraduate School, 13-14 November 2009.

Ramp, S., Rice, J., Stacey, M., Garfield, T., and Largier, J., “SF Bayweb 2009: Planting the Seeds of an Observing System in the San Francisco Bay,” *MTS/IEEE Oceans Conference*, Biloxi, Mississippi, 26-29 October 2009.

Ramp, S., Rice, J., Stacey, M., Williams, M., Largier, J., Garfield, T., and Bahr, F., “SF Bayweb 2009, Planting the Seeds of a new Observing System in the San Francisco Bay,” *Eastern Pacific Ocean Conference*, Victoria, British Columbia, Canada, 23-26 September 2009.

Rice, J., “Seaweb ASW Network and NGAS ’09,” *ONR Maritime Sensing Review*, Monterey, California, 18-20 August 2009.

Rice, J., “Seaweb Maritime Network,” *AUVSI/ONR Unmanned Systems Technology Review*, Orlando, Florida, 9-12 February 2009.

Rice, J., *TTCP Unet Collaborative Work Plan*, September 2009.

Rice, J., “Unet Undersea Networking,” *The Technical Cooperation Program Annual Meeting on ASW Systems and Technology*, Halifax, Nova Scotia, Canada, 21-25 September 2009.

Rice, J. and Ramp, S., “San Francisco Bayweb 2009,” *ACM SenSys Workshop on Under-Water Networking*, Berkeley, California, 3 November 2009.

Rice, J., Ong, C.W., Pinelli, R., and Coryer, M., “A Discovery Process for Initializing Ad Hoc Underwater Acoustic Networks,” *The Technical Cooperation Program Annual Meeting on ASW Systems and Technology*, Halifax, Nova Scotia, Canada, 21-25 September 2009.

Salvia, J., Gilbert, D., Brookshier, K., and Maier, W.B., “Easily Built Augmented Railgun: Design and Tests,” *California APS*, Monterey, California, 10 November 2009.

Sampayan, S., Caporaso, G., Chen, Y.-J., Carazo, V., Falabella, S., Guethlein, G., et al., “Ultra-Compact Accelerator Technologies for Application in Nuclear Techniques,” *10th International Conference on Applications of Nuclear Techniques*, AIP Conference Proceedings, 1194 pp. 69-79, 2009.

Singleton, D.R., Sinibaldi, J.O., Brophy, C.M., Kuthi, A., and Gundersen, M.A., “Compact Pulsed-Power System for Transient Plasma Ignition,” *IEEE Transactions on Plasma Science*, Vol. 37, Iss. 12, Part 1, pp. 2275–2279, December 2009.

Sinibaldi, J.O. and Ho, I., “Computational Studies on Convergent Detonation Fronts for PDE Applications,” *ONR Advanced Propulsion Conference*, July 2009.

Taheri, M.L., Browning, N.D., and Lewellen, J. (Eds.), *Symposium on Ultrafast Electron Microscopy and Ultrafast Science, Microscopy and Microanalysis Special Section*, 15, 2009.

Touse, M., M.P., Sinibaldi, J., Catterlin, J., and Karunasiri, G., “MEMS-Based Directional Microphone Mimicking the Biology of the Ormia Ochracea Fly,” *American Physical Society March Meeting*, Pittsburgh, Pennsylvania, March 2009.

Session Co-Chair, Working Group I (Injectors, Guns, and Cathodes), Energy Recovery LINAC Workshop, Ithaca, New York 2009.

PHYSICS

PRESENTATIONS

Lewellen, J.W., “The NPS-FEL Energy Booster/Injector Cavity,” UCLA High-Brightness Workshop, 2009.

Lewellen, J.W., “Revolutionary Advances in Free-Electron Lasers, or, Making Light the Right Way,” American Physical Society, California Chapter Meeting, 2009 (invited).

Lewellen, J.W., “What Can You Do With...?” UCLA High-Brightness Workshop, 2009.

Niles, S.P., et al., “Novel Quarter-Wave Booster/Gun Cavity,” Free-Electron Laser Conference, 2009.

Niles, S.P., et al., “Photoelectric Augmentation of a Thermionic Cathode with the NPS DC Electron Gun,” Free-Electron Laser Conference, 2009.

Niles, S.P., et al., “Status of the NPS Cathode and Superconducting Electron Gun Experiments,” Directed Energy Professional Society Annual Symposium, 2009.

BOOK

Cheney, M. and Borden, B., *Fundamentals of Radar Imaging*, SIAM Publishing, 2009.

PATENT

Larrazza, A., Catterlin, J., and Wolfe, D., “THz Reverse Micromagnetron,” Provisional Patent No. 61/248,301, September 2009.

TECHNICAL REPORTS

Baker, S.R., “Axisymmetric Finite-Element Modeling of a Bilaminar Flexural Disk Sonar Projector Element using the COMSOL Multiphysics Code,” Naval Postgraduate School Technical Report, NPS-97-09-001, December 2009.

Baker, S.R., “Quick-Look Comparison of Running Power-Averaged RMS Linear Acceleration Measured for MK149 and MK244 Fired Rounds -- Data from Live-Fire Exercises Conducted 18 August 2009 at China Lake (Jitter Test) on PHALANX CIWS Block 1B, System 347,” letter report prepared for and sent to Naval Sea Systems Command, September 2009.

**DEPARTMENT OF
SYSTEMS ENGINEERING**

**CLIFFORD WHITCOMB
CHAIRMAN**

SYSTEMS ENGINEERING

OVERVIEW:

Systems engineering focuses on the development of large and complex systems: how do the parts work together in an integrated system given the precise specification of the structure and behavior?

CURRICULA SERVED:

The Naval Postgraduate School (NPS) Department of Systems Engineering (SE) has 27 faculty members with primary appointments, 20 with joint appointments, and 2 administrative staff. We offer Master's degrees and will soon be offering a doctorate in systems engineering.

We have about 60 resident students and about 380 non-resident students. We work closely with the Wayne E. Meyer Institute of Systems Engineering at NPS, especially for student research programs. Our website is <http://www.nps.edu/se/>.

RESIDENT PROGRAMS OF STUDY:

The Systems Engineering Department supports two resident programs of study:

- Curriculum 580, the resident Master of Science in Systems Engineering (MSSE), is a seven-quarter degree program intended for technically oriented military officers, federal government civilians, and qualified international applicants. Students enrolling in the MSSE program may choose from one of three tracks:
 - Combat Systems Engineering
 - Network-Centric Systems Engineering
 - Ship Systems Engineering
- Curriculum 308, the resident Master of Science in Systems Engineering and Analysis (MSSEA), is an eight-quarter degree program intended primarily for Navy unrestricted line officers.

NON-RESIDENT PROGRAMS OF STUDY:

The Systems Engineering Department also supports three non-resident programs of study:

- Curriculum 311, the Master of Science in Systems Engineering via Distance Learning (MSSE DL), is an eight-quarter, distance-learning degree program intended primarily for federal government civilian scientists and engineers at Navy field activities.
- Curriculum 721, the Master of Science in Systems Engineering Management (MSSEM), is a distance-learning program intended for qualified military officers, senior enlisted, federal government civilians, and defense contractor civilians.
- The Systems Engineering Certificate Program provides the fundamentals of systems engineering to engineering duty officers and other officer communities without requiring the student to enroll in an NPS degree program.

RESEARCH THRUSTS:

Our research seeks to understand: 1) engineering methods and their application to problem solving, and 2) the spectrums of systems engineering – lifecycle, analyses, and integration of systems – balancing resources to ensure timely completion through hands-on research with Navy sponsors. Our mission is to:

- Prepare graduates to ensure national security by providing technical education in designing, building, operating, maintaining, and improving reliable, capable, effective, affordable, complex systems-of-systems that meet the user's needs when the user needs them.
- Perform research to improve and develop new systems engineering techniques and methods.
- Apply systems engineering techniques and methods to develop cost-effective, timely solutions to urgent national-security problems.

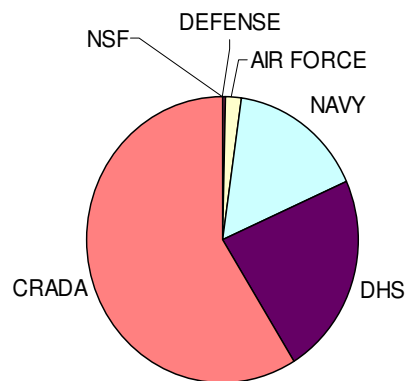
SYSTEMS ENGINEERING

Systems engineering research at NPS can be categorized into four specialization areas: systems engineering methodology, systems engineering applications, system simulation and modeling, and system suitability assessment.

- **Systems engineering methodology** involves the investigation of or development of tools and techniques for conceptualizing, designing, and developing systems. Study areas include discovery of fundamental principles of systems theory, elucidating the use of these principles through systems engineering tools and techniques, analyzing the conditions of employing the tools and techniques, and determining the efficacy of those tools and techniques. Specific methodology areas include system requirements generation, requirements allocation, system architecture, system dynamics and control, and risk engineering.
- **Systems engineering applications** involves the application of systems engineering processes to the solution of specific complex problems. This can include conceptual design of systems, investigation of issues associated with integration of system components into system segments, investigation of issues associated with integration of system segments into systems, and the analysis of case studies of successful and/or unsuccessful systems engineering applied to military acquisition programs. Specific application areas include combat systems integration, ship systems engineering, and enterprise systems engineering.
- **System simulation and modeling** involves the development of simulations and models of military systems, evaluation of the efficacy of these simulations and models in providing the information to accomplish systems engineering functions (especially system design requirements and comparison of alternative solutions), and investigation of the characteristics of simulations and models that lead to outputs that are useful in the systems engineering process.
- **System suitability assessment** involves the study of tools, techniques, and disciplines that permit the assessment of the suitability of systems in meeting requirements. Requirements can include performance, availability, operability, and cost. Specific suitability assessment areas include reliability engineering, system survivability, and system cost estimation and control.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Systems Engineering is provided below:



Size of Program: \$6.2M

SYSTEMS ENGINEERING

Clifford Whitcomb
Chair
831-656-3001
cawhitco@nps.edu

Robert Harney
Associate Chair for Research
831-656-2685
harney@nps.edu

Matt Boensel
Associate Chair for Operations
831-656-3489
mgboense@nps.edu

Gene Paulo
Associate Chair for Instruction
Associate Professor
831-656-3452
eppaulo@nps.edu

Walter E. Owen
Associate Chair for Distributed Programs and
Outreach and Senior Lecturer
636-925-2982
wowen@nps.edu

Charles N. Calvano
Professor Emeritus
831-656-2334
calvano@nps.edu

Kristin Giammarco
Lecturer
931-240-0761
kmgiamma@nps.edu

Rachel E. Goshorn
Assistant Professor and
C4I Chair
831-656-3835
goshorn@nps.edu

John M. Green
Senior Lecturer
831-656-1084
jmgreen@nps.edu

David A. Hart
Professor of Practice
831-656-3839
dahart@nps.edu

Thomas V. Huynh
Associate Professor
831-656-7568
thuynh@nps.edu

Jean M. Johnson
Lecturer
757-574-7563
jmjohnso@nps.edu

James L. Kays
Professor
Interim Naval Chairman
831-656-7860
jlkays@nps.edu

Edouard Kujawski
Associate Professor
831-656-3324
ekujawsk@nps.edu

Brigitte Kwinn
Lecturer
845-728-8118
btkwinn@nps.edu

Gary O. Langford
Senior Lecturer
831-656-1069
golangfo@nps.edu

Raymond Madachy
Associate Professor
831-847-0986
rjmadach@nps.edu

Richard (Dick) Millar
Associate Professor
301-757-0517
rcmillar@nps.edu

Gregory A. Miller
Senior Lecturer
831-656-2957
gamiller@nps.edu

Paul Montgomery
Associate Professor
703-568-1165
prmontgo@nps.edu

Donald S. Muehlbach, Jr.
Professor of Practice
858-259-9145
dmuehlba@nps.edu

David H. Olwell
Professor
831-656-3583
dholwell@nps.edu

Mark M. Rhoades
Senior Lecturer
831-277-9153
mmrhoad@nps.edu

Paul V. Shebalin
Senior Lecturer and Director,
Wayne E. Meyer Institute of
Systems Engineering
831-656-1047
pshebali@nps.edu

Mark R. Stevens
Senior Lecturer
831-656-7545
mstevens@nps.edu

William A. Solitario
Northrop Grumman Chair
of Systems Engineering
831-656-2546
wasolita@nps.edu

Ravi Vaidyanathan
Assistant Professor
831-656-2960
rvaidyan@nps.edu

SYSTEMS ENGINEERING

THE N8F CHAIR OF SYSTEMS ENGINEERING ANALYSIS

Charles N. Calvano, Professor of Practice
Department of Systems Engineering
Sponsor: Chief of Naval Operations

SUMMARY: Serving the President of the Naval Postgraduate School (NPS) and OPNAV N8F, the N8F Chair of Systems Engineering and Analysis (SEA) has general responsibilities related to the SEA Program at NPS and its response to and relevance to the Department of the Navy's (DoN) needs and priorities. Work includes liaison, oversight, advisory, and coordination roles related to ensuring the vigor, relevance, and excellence of the SEA curriculum and associated research. In carrying out these tasks, the chair will work with the NPS chairs of the Department of Systems Engineering and the Department of Operations Research, who provide oversight of the academic content of the curriculum. The principal investigator/chair will use sponsor-provided resources to promote research in support of SEA and DoN objectives and will pursue collaborative research opportunities for SEA students and supporting faculty across the NPS campus.

THE N8F CHAIR OF SYSTEMS ENGINEERING ANALYSIS

Charles N. Calvano, Professor of Practice
Department of Systems Engineering
Sponsor: Chief of Naval Operations

OBJECTIVE: To provide a rigorous educational foundation for Navy Unrestricted Line Officers in the skills necessary to be highly effective staff officers in OPNAV, other senior Navy staffs, and selected Fleet billets. The near-term objective is to provide graduates with the skills necessary to contribute to the determination of Navy/Defense needs, to the analysis of available options, to the development of systems to meet those needs, and to the analysis of the effectiveness of planned systems. The long-term objective is to improve the quality, effectiveness, and acquisition of Navy/Defense programs.

SUMMARY: The objective is met through a curriculum that provides a hybrid education including significant analytical coursework in the Operations Research Department, as well as a solid basis of systems engineering coursework taught in that department. A major capstone design project addressing a significant Navy or Department of Defense (DoD) problem or need is an integral part of the program and exercises the students in a realistic, team-performed study requiring them to apply both their analytical and systems engineering skills. The combination of an analytical foundation, an understanding of systems thinking and processes, and a realistic application of that knowledge to a real-world problem produces officers uniquely qualified to perform well in a wide range of billets occupied by Unrestricted Line Officers.

Serving the President of the Naval Postgraduate School (NPS) and OPNAV N8F, the N8F Chair of SEA has general responsibilities related to the SEA program at NPS and its response to and relevance to DoD/DoN needs and priorities. Work includes liaison, oversight, advisory, and coordination roles related to ensuring the vigor, relevance, and excellence of the SEA curriculum and associated research. In carrying out these tasks, the Chair will work with the NPS Chairmen of the Departments of Systems Engineering and of Operations Research, who provide oversight of the academic content of the curriculum.

The principal investigator/Chair uses sponsor-provided resources to: 1) promote research in support of SEA and DoD/DoN objectives (e.g., an investigation into the applicability of multi-criteria decision analysis (MCDA) to military applications); 2) pursue collaborative research opportunities for SEA students and supporting faculty across the NPS campus (e.g., liaison with Naval War College faculty concerning potential shared project work for the SEA capstone project to begin in January 2011); and 3) support student travel in pursuit of research goals, seek additional opportunities, and ensure that the curriculum evolves as necessary to continue to meet the objectives (e.g., students have traveled to an Office of Naval Research unmanned vehicle research review; to a conference on modeling and simulation; and other Navy and professional meetings related to their work at NPS).

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PRESENTATIONS:

Numerous presentations by both faculty members and students to (among others): each student project is presented at NPS to a wide spectrum of invited attendees from Navy, industry, and academia; Commander Naval Mine and Anti-Submarine Warfare Command, plus staff; Program Executive Officer, Littoral and Mine Warfare; Commander Navy Meteorology and Oceanographic Command; members of the Naval Surface Warfare Center, Panama City, Florida; the National Defense Industry Association Conference on Mine Warfare; the Center for Naval Analyses; and the International Council on Systems Engineering chapters.

PROJECTS DIRECTED:

SEA students, as a team, perform a capstone design project in lieu of thesis. The selection and shaping of these projects is a responsibility of the Chair, who is aided by a faculty member who provides close supervision of student work. Recent projects have included: 1) "A Systems Approach to Defeating Maritime Improvised Explosive Devices in U.S. Ports," December 2008; 2) "A Systems Approach to the Design of a Maritime Phase Zero Force for the Year 2020," June 2009; and 3) "An Architecture for the Command and Control of Unmanned Vehicles" (to be completed in June 2010).

TECHNICAL REPORTS:

Calvano, C., "An Architecture for the Command and Control of Unmanned Vehicles," June 2010 (to be completed).

Calvano, C., "A Systems Approach to Defeating Maritime Improvised Explosive Devices in U.S. Ports," Naval Postgraduate School Technical Report, NPS-SE-08-010, December 2008.

Calvano, C., "A Systems Approach to the Design of a Maritime Phase Zero Force for the Year 2020," Naval Postgraduate School Technical Report, NPS-SE-09-006, June 2009.

DETERMINATION OF ADVANCED LEADING INDICATORS OF PROGRAM TECHNICAL ISSUES

Ronald R. Carlson, Professor of Practice
Department of Systems Engineering
Sponsor: Naval Air Systems Command

OBJECTIVE: To identify advanced leading indicators of acquisition-program technical problems so that they can be identified early and so that corrective actions put in place to ensure successful program completion.

SUMMARY: Professor Carlson started working on this research late in 2009, and NAVAIR has continued this project into 2010. The work performed during 2009 focused on identifying what data would be most useful in determining program health and then determining if that data was readily available. It was determined that continuous data for almost any problem area was not readily available, and the task turned to evaluating available data and searching archives for missing and additional information. In 2010, data collection and analysis will begin for aircraft weight, program manning, software and operational tests.

FORMAL MODELING OF USER-DEMAND-BASED NETWORK SYSTEMS

Kristin Giammarco, Lecturer
Department of Systems Engineering
Sponsor: U.S. Army Communications-Electronics Research, Development, and Engineering Center

OBJECTIVE: To provide subject matter expertise and guidance to the CERDEC Space and Terrestrial Communications Directorate with respect to formal methods as they apply to architecture modeling.

SUMMARY: In both the public and private sectors, systems engineering analysis studies are used to inform a range of decisions, from selecting among low-level design alternatives to conducting high-level portfolio management. These studies are conducted to help various stakeholders make and justify decisions that have a lasting effect on a system throughout its lifecycle. The quality of the data used in these analyses can have a strong influence on the outcome of these decisions. This research investigated the application of formal methods to architecture model quality assessment. These methods were used to create sets of measures and criteria relevant in the systems engineering problem domain that can be tailored for different events, analytics, and decision points. Using formal methods, stakeholders can decompose and express architecture data quality expectations unambiguously, and in a way that is abstract and independent of tool. This project will continue into CY10; the work described above was accomplished in CY09.

PUBLICATION:

Giammarco, K., "Formal Methods for Architecture Model Assessment in Systems Engineering," *Proceedings of the 8th Annual Conference on Systems Engineering Research*, Hoboken, New Jersey, March 2010 (accepted).

KEYWORDS: Formal Methods, Architecture, Data Modeling

MODELING AND ASSESSMENT OF THE C4ISR ON-THE-MOVE EVENT 09 ARCHITECTURE

Kristin Giammarco, Lecturer

Department of Systems Engineering

Sponsor: U.S. Army Research, Development, and Engineering Command

OBJECTIVE: To conduct and apply research in architecture formalization using multiple C4ISR architectures provided to PM C4ISR On-the-Move (OTM) by key Army stakeholders; and to support C4ISR OTM Event 09 (E09) execution and analysis by leading the development and evolution of the event integrated architectures.

SUMMARY: The E09 integrated architecture was defined in terms of the schema of the commercial systems engineering tool, CORE, to study how the complexities of a real-world system-of-systems and the intricate operational and technical requirements of PM C4ISR OTM could be described in a more structured manner than that which has previously been used. It was found that the CORE schema was adequate for capturing the data elements and relationships that PM C4ISR OTM presently tracks in a manually intensive manner. An application of formal methods was used to specify one overarching, SoS-level requirement of interest in the form of logical rules. Specifically, the data model and associated logical rules can be used to enable the early detection of conflicts among live components that are planned for use in more than one experiment during the same timeframe. C4ISR OTM E09 provided a unique venue with actual architecture datasets and real SoS-level problems that inspired research into more formal ways to relate and analyze architectural data. The PI served as Chief Technical Editor for the E09 final report near the end of CY09. This summary reports on the work that was accomplished in data modeling and analysis for the E09 integrated architecture; the project will continue into CY10.

PUBLICATION:

Giammarco, K., "Developing a Common Data Model," *PM C4ISR On-the-Move Event 09 Final Report*, RDECOM CERDEC PM C4ISR OTM (chapter accepted for publication).

OTHER:

A structured model of the E09 Integrated Architecture was developed using CORE, the Vitech Corporation's systems engineering tool.

KEYWORDS: Architecture, Data Modeling, C4ISR, System of Systems

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THE C4I CHAIR PRE-LAUNCH PHASE

Rachel Goshorn, Assistant Professor

Department of Systems Engineering

Sponsor: Program Executive Office Command, Control, Communications,
Computers, and Intelligence

OBJECTIVE: To begin C4I Chair efforts and to synchronize Naval Postgraduate School (NPS) and PEO C4I S&T efforts.

SUMMARY: PEO C4I requested that the principal investigator (PI) be their C4I Chair at NPS. Before the MOA went through (January 2010), PEO C4I funded the PI to begin the C4I Chair duties. The work carried out over the summer of FY09 (and continued in fall 2009) was in response to a request from PEO C4I to prepare for assisting PEO C4I in FY10 as C4I Chair at the Naval Postgraduate School. In FY10, assisting PEO C4I will require: interfacing with PEO C4I on gathering potential theses, capstone projects, faculty research topics and circulating with the Naval Postgraduate School schools, departments, institutes, academic groups, and research centers. Workshops in the fall and spring quarter will be hosted at NPS to assist in circulating these topics, and a website will be hosted at NPS to also circulate these topics. In order to prepare for the FY10 position of assisting PEO C4I, several visits to PEO C4I were carried out over the summer, along with attending a demonstration (requested by PEO C4I). The visits to PEO C4I over the summer encompassed working closely with APEO for Science and Technology (S&T) and meeting with PEO C4I, program managers, technical directors, S&T, etc., to gather topics and discuss NPS research and curricula. The PEO C4I-supported work covered trips to PEO C4I (about one per month this summer) and one visit to the Empire Challenge demonstration in China Lake; labor for the trips was covered as well as a few weeks of labor to carry out additional preparations. Additional preparations included working with ITACS Business Solutions Group to develop a website for hosting the C4I Chair information (accessible by NPS and PEO C4I, with various levels of access), working with NPS to socialize the C4I Chair and PEO C4I, interacting with NPS (Dean of Research) on getting up to speed with current research and curricula, developing a plan for matrix mapping between NPS and PEO C4I, and working with PEO C4I on gathering research topics (theses, capstone projects, faculty/labs research, etc.). In September 2009, the C4I Chair was announced to NPS at a briefing, where the PEO C4I Technical Director briefed NPS on PEO C4I's Masterplan, which is the basis of mapping between NPS and PEO C4I. Since the summer funding, the principal investigator has been carrying out the C4I Chair duties, and the MOA was signed by PEO C4I and NPS in January 2010. It was summarized well in the NPS public article at: <http://www.nps.edu/About/News/NPS-Stands-Up-New-C4I-Chair-.html>.

PRESENTATIONS:

Several presentations were made under this research.

THESIS DIRECTED:

Haase, D., "Network-Centricity in Consolidated Afloat Network Enterprise Services (CANES)," Master's Thesis, Naval Postgraduate School, Spring 2010.

THE NAVAL POSTGRADUATE SCHOOL C4I CHAIR PRE-LAUNCH PHASE

Rachel Goshorn, Assistant Professor

Department of Systems Engineering

Sponsor: Program Executive Office Command, Control, Communications,
Computers, and Intelligence

OBJECTIVE: The work carried out this summer is in response to a request from PEO C4I to prepare for assisting PEO C4I in FY10 as the C4I Chair at the Naval Postgraduate School. In FY10, assisting PEO C4I will require interfacing with PEO C4I on gathering potential theses/projects, faculty research topics, and circulating with Naval Postgraduate School (NPS) schools, departments, institutes, academic groups, and research centers. In addition, in FY10, workshops in the fall and spring quarter will be hosted at NPS, and

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topics will be circulated via an NPS website. To prepare for the FY10 C4I Chair, several visits to PEO C4I are required over the summer, along with attending a demonstration (requested by PEO C4I). The visits to PEO C4I over the summer are, working closely with APEO for S&T, to meet with PEO C4I, APEOs, program managers, technical directors, S&T, etc., to gather topics and discuss NPS research and curricula.

Additional goals are to develop a memorandum of understanding for signature for FY10, develop a detailed plan for FY10, work with ITACS to develop a website, schedule a fall FY10 workshop, and interact with NPS (Dean of Research) on getting up to speed with current technologies.

THE NAVAL POSTGRADUATE SCHOOL NET-CENTRIC ENTERPRISE SYSTEMS ENGINEERING RESEARCH PROGRAM

Rachel Goshorn, Assistant Professor

Department of Systems Engineering

Sponsor: PEO EIS

OBJECTIVE: To establish a net-centric systems engineering (NCSE) research capability at the Naval Postgraduate School to support the PEO EIS and the Navy in the acquisition and deployment of next-generation enterprise and C4I systems.

SUMMARY: PEO EIS funding for the development of Network-Centric Systems Engineering Education (CO-PI) was requested in CY08 and came through, but due to logistics funding came through for the principal investigator (PI) in CY09. Based on PEO EIS funding, the PI developed and taught Artificial Intelligence Systems Engineering II (continued from AI SE I of fall 2008), which overlaps with research conducted in the area of AI Net-Centric Systems. The PI developed Artificial Intelligence Systems Engineering II (fall 2009), and taught it under SE 4900 (Advanced Topics in Systems Engineering). The class had about thirteen students, where an artificial intelligence net-centric system from AI SE was further developed and implemented, which the students called the "Watchman System." For the Artificial Intelligence Systems Engineering II, an open house demo was given to the whole school. Several faculty members from across campus attended and provided very positive feedback. A handful of advanced topics were taught throughout CY09 on AI NCSE. More details are provided in the teaching section. In these courses, the PI developed and implemented new teaching techniques for systems engineering and artificial intelligence in network-centric systems-engineering applications. In this course, DoD/DON/DHS applications were emphasized, specifically the Global War on Terror and homeland security applications. The systems developed are proof-of-concept systems, and the students can apply knowledge gained here to leading-edge GWOT and HLS problems to influence future systems and solutions.

In CY09, the PI carried out research for NCSE courses, lab, and research development. The PI further developed the NCSE Lab, by adding more systems into the network-centric system, to create a system of systems (SoS) environment, specifically a Net-Centric AI SoS. The overall systems in the NCSE AI SoS are: command and control enterprise system, cyber-security system, fixed camera system, kiosk system for mobile security, internal unmanned vehicles system, external unmanned ground vehicles system, and unmanned airborne vehicles system. The systems are integrated through IP to the C2 Enterprise System. Each system has an infrastructure (sensors, communications, software, etc.) and automation (detection, identification, prediction, and reaction). In summary, the courses are on hold to be proposed, but the material for the resident and certificate courses is developed. Leading-edge research was carried out on automation of behavior analysis for detection, identification, prediction, and reaction (DIPR) in distributed sensor systems and published in a Springer Handbook. Wiley is interested in a textbook based on this book chapter. Out of this research, the PI was interviewed by a system-level design community for an online video interview, and an interview from Forbes.com on this research was published.

The newest systems conceived and launched in FY09 are the external UGV system and the UAV system, which introduce outdoor mobile ground and airborne robots into a network-centric wireless network. The Network-Centric Systems Engineering (NCSE) Lab, in the Systems Engineering Department, purchased a dozen ground mobile robots and two airborne mobile robots for the purpose of introducing mobile wireless sensor nodes into the existing fixed system in the network-centric AI lab.

In addition to the NCSE Lab and AI SE courses, in this research, the PI developed an outline for seven courses for the resident NCSE track, and a four-course NCSE certificate based on the request from ASN RDA CHENG. ASN RDA CHENG requested that a four-course, network-centric systems-engineering

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certificate be developed based on the PI's NCSE model and recommendations for the MSSE NCSE track resident education. Three of the seven courses were developed and taught through advanced studies and topics courses in systems engineering. Five thesis students assisted with content towards these certificate courses as well. A summary of the outcome of these is below:

Updated NCSE Track Learning Objectives:

Systems Engineering for Network-Centric Warfare/Ops (NCW/NCO)

- Apply systems engineering and architecting methods to the development of complex systems of systems, including enterprise and distributed artificial intelligence systems.
- Understand the technical aspects of enterprises, distributed systems, middleware, disadvantaged users, and artificial intelligence systems engineering.
- Understand the risks, issues, and trade-offs of using current and projected network and collaborative technologies, including security and information assurance.
- Understand the principles that underlie the research, design, engineering, development, and operation of modern, artificial, intelligent, software-intensive network systems.
- Understand the principles for operating, evaluating, and managing network-centric systems within an end-to-end system lifecycle perspective.
- Understand the fundamental concepts and principles involved in the design, engineering, operation, and use of network-centric warfare and operations systems.

Proposed Courses (with two existing):

1. **NCSE#1 Fundamentals of Network-Centric Artificial Intelligence Systems Engineering I**
 - Initial content developed.
2. **NCSE#2 Fundamentals of Network-Centric Artificial Intelligence Systems Engineering II**
 - Initial content developed.
3. **NCSE#3 Fundamentals of Network-Centric Systems Engineering**
 - Taught Spring 2008 (*initial content developed and taught*)
4. **NCSE#4 Network-Centric Artificial Intelligence Systems Engineering I**
 - Taught Fall 2008 (*continued to be developed*)
5. **SE3501 Distributed Systems Engineering**
 - (*approved course, content further developed to be in synch with the model*)
6. **SE4501 Network-Centric Enterprise Design and Systems Engineering**
 - (*approved course, content further developed to be in synch with the model*)
7. **NCSE#5 Network-Centric Artificial Intelligence Systems Engineering II**
 - Taught Winter 2009 (*continued to be developed*)

NCSE Topics to be referenced in the four course certificate descriptions:

- NCSE Topic 1: Introduction to Net-Centric Enterprise Systems/Services Engineering (survey-type topic of NCSE Core, in parallel tools for networking)
- NCSE Topic 2: Communications Fundamentals for Net-Centric Systems Engineering (survey-type topic, tools for communications between all approaches)
- NCSE Topic 3: Artificial Intelligence (AI), Feature Extraction, and Classification Fundamentals for Net-Centric Systems (tools for middle, bottom-up, side-view approach)
- NCSE Topic 4: Net-Centric Enterprise Systems/Services (top-down approach)
- NCSE Topic 5: Smart Sensor Networks for Net-Centric Enterprise Systems/Services Engineering (bottom-up approach)
- NCSE Topic 6: Net-Centric Systems Design: Major Project of Hardware Connected Together with Software and Make it Work (Bottom-Up and Top-Down) (top-down, bottom-up, middle approach)
- NCSE Topic 7: Major Research Project – Disadvantaged Users (Comms to the Tactical Edge) (side-view, with top-down, bottom-up, and middle approach)

Four-course DoD NCSE certificate courses are outlined below:

NCSE Certificate Course 1

Course 1: Introduction to Network-Centric Enterprise Systems Engineering

- (NCSE Core Topic 1)
- Survey course on the NCSE certificate (overview on NCSE certificate four courses)
- Survey on NCSE Top-Down, Bottom-Up, Middle, Side-View Approaches
- Current Net-Centric Applications
- Fundamentals of Networking – Systems Engineering Fundamentals
- Carry Out Project on the Front-End Systems Design of Net-Working

NCSE Certificate Course 2

Course 2: Network-Centric Enterprise Systems/Services (Top- Down Approach)

- (NCSE Core Topics 2 and 4)
- Top-Down Approach (Service Oriented Architectures, Enterprise Services, DISA NCES, Google Apps, Collaboration, IA, Security, Data Discovery, T&E for Services: JITC testing, etc.)
- Fundamentals of Communications
- Supportability for NCSE Services
- Carry out Project on the Front-End Systems Design of Top- Down Approach

NCSE Course 3

Course 3: Smart Sensor Networks/Middleware for Network-Centric Enterprise Systems Engineering (Bottom-Up and Middle Approach)

- (NCSE Core Topics 3 and 5)
- Bottom-Up and Middle Approach
- Fundamentals of AI, Feature Extraction/Classification (Data Discovery)
- Fundamentals of distributed smart sensor networks (scale to networks, where sensors represent ships, submarines, shore- sites, etc.)
- Smart push/smart pull (publish/subscribe or produce/consume), from a top-down approach understand how to intelligently pull information/data of interest and from a bottom-up approach understand how to push information/data of interest
- NCSE Architectures (e.g., DoDAF)
- Carry Out Project on the Front-End Systems Design of Bottom-Up Approach

NCSE Course 4

Course 4: Network-Centric Enterprise Systems Design

- (NCSE Core Topics 6 and 7)
- Understand Side View - Disadvantage User
- SE Project Design and Management
- Given mission requirements/needs and capabilities, design and implement a network-centric system (top-down, bottom-up, and middle, connecting the software and hardware) and extend to/from disadvantaged user.

PUBLICATIONS:

Goshorn, R.E., “The 32nd Annual German Conference on Artificial Intelligence,” *German AI Journal*, December 2009 (submitted). (After January 2010, this will be a Springer Journal.)

Goshorn, R.E., Goshorn, D.E., Goshorn, J.L., and Goshorn, L.A., “Behavior Modeling for Detection, Identification, Prediction, and Reaction (DIPR) in AI Systems Solutions,” *Handbook of Ambient Intelligence and Smart Environments*, Springer U.S., 978-0-387-93807-3 (print), 978-0-387-93808-0 (online), pp. 669-700, 1 October 2009.

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CONFERENCE PUBLICATIONS:

Goshorn, D., Goshorn, R., Goshorn, J., and Goshorn, L., "Abnormal Behavior Classification and Alerting through Detection, Identification, Prediction, and Reaction (DIPR) System Applied to a Multi-Camera Network," *German Conference on Artificial Intelligence, Workshop on Behavior Monitoring and Interpretation*, September 2009.

Vanatta, N., Miller, G.A., and Goshorn, R.E., "A Method to Analyze Network-Centric Capabilities for Agile C2 for Combat Support Soldiers in Southwest Asia," *14th International Command and Control Research and Technology Symposium (ICCRTS)*, Washington, D.C., 15-17 June 2009.

PRESENTATIONS:

The PI presented several briefs on research and curricula development.

Goshorn, R.E., "Distribution of Intelligent Ad-Hoc Satellite Nodes – A Paradigm Shift in Space (Network-Centric Systems of Systems)," National Reconnaissance Office Systems Engineering Conference, 4 August 2009 (invited).

THESES DIRECTED:

Brandon, L., "Allowing the Advantaged User in a Network Centric System to Get through the Disadvantaged Interface," Master's Thesis, Naval Postgraduate School, September 2009.

De Soto, K., "An Assessment, Survey, and Systems Engineering Design of Information Sharing and Discovery Systems in a Network-Centric Environment," Master's Thesis, Naval Postgraduate School, December 2009.

Nesteruk, E., "Security Considerations for Network-Centric Weapon Systems," Master's Thesis, Naval Postgraduate School, September 2009.

Schafer, D., "A Systems Engineering Survey of Artificial Intelligence and Smart Sensor Networks in a Network-Centric Environment," Master's Thesis, Naval Postgraduate School, September 2009.

Stubblefield, P., "Security Enhancement of the Littoral Combat Ship Class Utilizing an Autonomous Mustering and Pier Monitoring System," Master's Thesis, Naval Postgraduate School, March 2010.

Vergara, G., "A Recommended Framework for the Network-Centric Acquisition Process," Master's Thesis, Naval Postgraduate School, September 2009.

MARITIME SURVEILLANCE SYSTEMS PROGRAM SUPPORT

John M. Green, Senior Lecturer

Department of Systems Engineering

Sponsor: Program Executive Office for Littoral and Mine Warfare

OBJECTIVE: To provide the principal academic investigator with scientific and technical support to investigate the hardware and software architecture for a next-generation MSS processing, display, and visualization capability; to provide scientific input at working groups and program reviews as part of the next-generation working group; and to propose functional allocations and methods for evaluating new concepts and resources.

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A SOFTWARE PRODUCT LINE APPROACH TO OPEN ARCHITECTURE AND NAVY WEAPONS SYSTEM ACQUISITION

John M. Green, Senior Lecturer

Gregory A. Miller, Lecturer

Department of Systems Engineering

Sponsor: Naval Postgraduate School Acquisition Research Program

OBJECTIVE: To show the viability of software product lines in developing warfare-domain-specific systems that are built from components that allow software reuse across multiple, diverse platforms (e.g., submarines and destroyers). While the basic approach has been demonstrated by others, the intended research will address two new issues. First, the principle investigators (PIs) will look at the role of simulation and its ability to support development of both operational and system architectures. Second, the PIs will evaluate methods by which legacy system elements can be captured and incorporated with the as yet undefined CG(X) system.

SUMMARY: This is an ongoing project that continues into 2009. Two student-based efforts were completed in March 2009. One was a 30-person MSSE capstone project that evaluated methodologies related to the implementation of a combat system architecture based on software product lines. The second effort was a PD-21 thesis that looked at the relationship of the Department of Defense Architecture Framework's relationship to capturing the outcome of the requirements process. Green and Miller extended the concepts discussed in Green's original paper, the results of which were presented at the NDIA Systems Engineering Conference.

There are several papers in progress, including one for the NPS 2009 acquisition symposium.

PUBLICATION:

Green, J.M., "Applying Open Architecture Concepts to Mission and Ship Systems," *Naval Engineers Journal ASNE*, Day 2008.

CONFERENCE PUBLICATION:

Green, J.M. and MSSE Cohort 6, "Application of Model-Based Systems Engineering Methods to Development of Combat System Architectures," *Proceedings of the 6th Annual Research Symposium*, NPS-AM-09-025, Monterey, California.

PRESENTATIONS:

Green, J.M., "Application of Model-Based Systems Engineering Methods to Development of Combat System Architectures," 6th Annual Research Symposium, Monterey, California, May 2009.

Green, J. and Miller, G., "Applying Open Architecture Concepts to Mission and Ship Systems," NDIA Systems Engineering Conference, San Diego, California, October 2008.

THESIS DIRECTED:

Childs, J., et al., "Application of Model Based Systems Engineering Methods to Development of Combat System Architectures," Master's Capstone Project, Naval Postgraduate School, March 2009.

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THE USE OF NETWORK-CENTRIC PERSONNEL-MONITORING DEVICES, GLOBALLY DISTRIBUTED THROUGH AN IP-BASED SENSOR MANAGEMENT ARCHITECTURE AND DISPLAY

LT Alex Gutierrez, USN, Student

Department of Systems Engineering

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: To select, integrate, and test commercial, off-the-shelf components to develop a system that can accurately monitor an individual's vital signs, transmit those throughout an established sensor-management network, and display the information within the combined C2 display; and, in parallel, to document and evaluate the systems engineering process used in the development of personnel-monitoring devices.

TUNNEL DETECTION RESEARCH

Thomas V. Huynh, Associate Professor

Gary O. Langford, Senior Lecturer

Department of Systems Engineering

Sponsor: Customs and Border Protection

OBJECTIVE: To 1) analyze and prioritize threats in terms of stakeholders, lifecycle issues, economic issues, and signatures; 2) provide sensor models to systems simulation; and 3) perform a cost assessment.

SUMMARY: This work provided for the analysis of the threats to cross-border trafficking from a U.S. perspective, with primary emphasis on the Mexican border. The analysis included an assessment of the supply chains required by tunnel construction and operations, the resolution of tunnel lifecycle issues, and an assessment of the economics of tunnel construction and operations.

The findings presented in the final report were based on extensive analyses of supply chain logistics, operational realism, and current interdictions.

The second task reported on the underlying assumptions and the scope of sensor modeling that was necessary to define the sensor parameters and values.

The third task reported on a cost assessment analysis, which included a description of costing methods, cost model, cost parameterization of sensor performance data, and error analysis.

TECHNICAL REPORT:

Langford, G. and Huynh, T., "Cocaine Tunnel Threat Assessment," Naval Postgraduate School Technical Report, NPS-SE-09-010, September 2009.

TUNNEL DETECTION RESEARCH

Thomas V. Huynh, Associate Professor

Department of Systems Engineering

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To support customs and border protection in selecting a sensor mix for detecting tunnels.

SHARE TRANSITION SUPPORT AND REPOSITORY TOOL DESIGN

Jean Johnson, Lecturer

Department of Systems Engineering

Sponsor: Program Executive Office, Integrated Warfare Systems 7.0

OBJECTIVE: The SHARE Repository Pilot Program will be discontinued in September 2009. The sponsor of the program and other stakeholders are in the process of determining how to transition the

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lessons learned and assets accumulated into related repository efforts going forward. An objective of this research is to provide input to these planning efforts based on previous and future research.

A second objective is to develop preliminary designs for repository tools that allow for guided navigation of artifacts in software repositories. These tools will take advantage of the improved repository framework developed during the previous effort. The designs will be used in future research as part of a focus group study of repository owners.

SHARE TRANSITION SUPPORT AND REPOSITORY TOOL DESIGN

Jean Johnson, Lecturer

Department of Systems Engineering

Sponsor: PEO, Integrated Warfare Systems 7.0

OBJECTIVE: To provide input into the planning efforts as the SHARE repository is transitioned to its next iteration. A second objective is to develop preliminary designs for repository tools that allow for guided navigation of artifacts in software repositories.

SUMMARY: The support provided to the ongoing PEO IWS efforts related to software repositories included meeting attendance (via telephone when possible), paper and related materials reviews, and contributions to the plans under development as requested by the sponsor activity.

To develop the preliminary designs for the repository tools, the following activities were initiated:

- Refined the repository framework previously provided based on feedback and the direction of future activities.
- Developed preliminary designs for a search and discovery tool that will employ methods not currently provided by existing repository toolsets, enabled by the contextual information provided by the repository framework.
- Developed preliminary designs for an asset submission tool, which will be the input mechanism for developers entering items into the repository.

As planned in the initial project proposal, this work continues into CY2010. Continued work is necessary to refine the tool specification and develop implementation guidance. Further, an evaluation plan including sponsor feedback and a focus group study has been proposed for future funding.

CONFERENCE PUBLICATION:

Johnson, J. and Blais, C., "Ontology-Based Solutions for Software Reuse," *Proceedings of the 6th Annual Acquisition Research Symposium*, Monterey, California, 13-14 May 2009.

THE NAVAL CHAIR OF SYSTEMS ENGINEERING AND THE SYSTEMS ENGINEERING RESEARCH PROGRAM

James L. Kays, Professor and Naval Chair of Systems Engineering

Department of Systems Engineering

Sponsor: PEO Integrated Warfare Systems, Office of the ASN (RD&A), CHSENG

OBJECTIVE: To promote high-quality graduate systems engineering education that supports both the ASN (RD&A) CHSENG and PEO IWS missions; to conduct current research in topics related to ASN (RD&A) CHSENG, NAVSEA, and PEO IWS; and to stimulate and support research by Naval Postgraduate School faculty and students.

SUMMARY: These two research projects are essentially one project with two sponsors. The funds provided by the sponsors were focused on supporting the growth and enhancement of systems engineering (SE) education in response to and aligned closely with the needs of the Navy and the sponsors. This involved applying funds to the most critical needs of Curricula 580 and 311, including the support and enhancement of an evolving resident and nonresident SE faculty, support and enhancement of the

educational experiences of SE students, and assisting with the development of the infrastructure essential for success.

More specifically, funds were allocated to student travel related to theses and the enhancement of their educational experiences, faculty travel aligned with their research and professional development, upgrading equipment and facilities related to sustaining both resident and nonresident systems engineering programs, and preparation for the ABET visit in 2010. The focus and allocation of funds were also in accord with the guidance in the 22 August 2008 MOA signed by both PEO IWS and ASN RDA CHSENG, who sponsor and fund the Naval Chair.

Related to the above, an important role of the Naval Chair is to serve as the executive secretary of the Systems Engineering Oversight Council (SEOC). This was particularly true in 2009, as the Navy expanded its efforts to reestablish systems engineering competencies in the work force. The SEOC consists of the Navy's senior systems engineering leaders and is chaired by ASN RDA CHSENG. It includes the sponsor of Curriculum 580 PEO IWS and all Navy SYSCOM Chief Systems Engineers. In short, the SEOC is the interface between the Department of the Navy (DoN) systems engineering community and its source of graduate systems engineering education, the Naval Postgraduate School (NPS). The focus of the SEOC is an additional influence on how funds are allocated.

The Naval Chair of Systems Engineering is responsible for assuring timely and responsive SEOC meetings and communications to assure that NPS responds to Navy needs with high-quality systems engineering education. The SEOC meeting agendas are consistent with and derived from the purposes and focus of the SEOC. For example, the meetings in January and August 2009 focused on the following:

1. Provide information and feedback to SEOC members on NPS plans to address the DoN systems engineering educational requirements as laid out in the SEOC Core Expectations, including:
 - a. Responsiveness to the systems engineering competency (i.e., graduate SE education) requirements of the Naval Acquisition Community (NAC);
 - b. Responsiveness to fulfilling the graduate SE education component of the systems engineering competency requirements of the Naval Acquisition Community (NAC), including:
 - i. education and curricula alignment to the needs of the workforce and partitioned into levels of SE (i.e., mission, system of systems, systems and component)
 - ii. ABET accreditation of systems engineering curricula
 - a) NPS single point-of-entry for SE education
 - b) NPS response to serving non-resident students (distance learning and embedded faculty at DoN locations)
 - c. Status of ABET accreditation of systems engineering curricula
 - d. NPS single point-of-entry for SE education
 - e. NPS response to serving non-resident students, including distance learning and embedded faculty at DoN locations
 - f. NPS need to offer flexible alternatives to meet SE education needs of NAC
2. Provide strategic feedback and advice to the President and the Provost, NPS, on matters related to:
 - a) NPS support for strategic goals for DoN systems engineering
 - i. Progress in achieving the DoN strategic goals for systems engineering
 - ii. Adjustments to the systems engineering curriculum at NPS to enhance NPS support for the DoN strategic goals for systems engineering
 - b) Provide operational feedback and advice to the President and the Provost, NPS, on matters related to the effectiveness and continuous improvements of systems engineering education provided by NPS to the DoN workforce

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THREAT ANALYSIS OF DISRUPTORS IN THE STRAITS OF MALACCA AND SINGAPORE

Gary O. Langford, Senior Lecturer
Department of Systems Engineering
Sponsor: National University of Singapore

OBJECTIVE: To formulate a framework to facilitate applied research that is expected to result in very cost effective and practical recommendations to address and resolve some outstanding issues related to disruption of commerce in the Straits of Malacca and Singapore; and to promote academic discussion to improve the theoretical and programmatic foundations of intelligence using open-source data and information.

SUMMARY: This work addressed the cognitive patterns of people characterized as “terrorists,” their organization and strategies, and concluded by offering insights into the future of the “war on terror” from a U.S. perspective.

The findings presented in this report were based on an extensive set of interviews with technical analyses of terrorists. The interviews and technical analyses provided in-depth information on their cognitive patterns, motives, habits, decision-making, organization, and conflict strategies, including attack and defense strategies and compromise and negotiation strategies.

The term “terrorist” challenged the objectivity of the study on “terrorism.” The unabashed connotation of the term and its emotional triggers got in the way of dispassionately looking at the world to which it refers. A better term than terrorist was not found.

A second task (to deliver a course on command and control architectures at the National University of Singapore) was negotiated during 2009. A set of presentation materials was delivered in October 2009.

A third task (to prepare a final report which discusses the presentation materials from the aforementioned course) is scheduled for final delivery by 30 March 2010.

PRESENTATION:

Langford, G., “Systems Engineering Design and Architectures for Command and for Control: A Short Course,” March 2009.

SOFTWARE COST-ESTIMATION METRICS

Ray Madachy, Associate Professor
Department of Systems Engineering
Sponsor: U.S. Air Force Cost Analysis Agency

OBJECTIVE: To establish a robust and cost-effective software-metrics collection process and knowledge-base that supports the legitimate data needs of the Department of Defense (DoD), while imposing minimal burdens on the acquisition workforce and its industry partners. Further objectives are to enhance the utility of the collected data to oversight and management entities and to academic and commercial research into improved cost estimation of future DoD software-intensive systems and the DoD cost community.

SUMMARY: Prepared draft versions of the cost estimation manual and accepted presentations on metrics and data analysis. They included work on metrics implications of future DoD and technology trends, requirements-to-code expansion ratios, systems-of-systems estimation, metrics definitions, SRDR data collection and analysis, code-count tool extensions, software-maintenance data analysis, incremental development productivity decline effects, and COCOMO II data trends.

Used this material to set the context and develop plans for the SERC-AFCAA Software Estimation Metrics Workshop. Obtained feedback on the results to date and gained consensus on the content, priorities, and next set of steps for an initial incremental set of recommended improvements to the current DoD Software Resources Data Report Form (SRDR).

Continued assessment of SRDR data submissions; continued identification of data definition and completeness issues; extended initial analysis of well-defined SRDR data points; continued work on common sizing, reuse, and effort scope definitions; and prepared the next draft of data definitions, including a new approach to complexity and constrainedness rating scales.

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Meetings were held at SERC ASRR to prioritize the exploration of alternative SIS cost-estimation methods via data mining of SIS size, effort, and process data, and identified initial methods to investigate.

Updated plans for SRDR data analysis, metrics definitions, sizing and productivity definitions and data analyses, and worked with sponsor to prioritize candidate improvements for SRDR data reporting and update drafts of the relevant AFCAA Software Cost Estimation Metrics Manual chapters.

ADVANCED SENSOR SYSTEMS AND SYSTEM DYNAMIC IDENTIFICATION FOR NAVAL AVIATION SYSTEMS T&E AND HEALTH MANAGEMENT (CBM+)

Richard C. Millar, Associate Professor

Department of Systems Engineering

Sponsor: Naval Air Systems Command

OBJECTIVE: To develop technologies that enable enhanced weapon-system health management. Three subsidiary objectives addressed by this research are: a) robust sensors for application in extreme environments exposed to high temperature, pressure, vibration, and shock; b) open system instrumentation/sensor systems reducing the cost and time for weapon-system development and qualification test; and c) methods for assessing the dynamic characteristics (system identification) of weapon systems and their critical control components. Dr. Millar has been working over the past couple of years with the Joint Strike Fighter Joint Program Office (JSF JPO) to advance these technologies by proposing SBIR topics, assessing proposals, and as the technical point of contact (TPOC) guiding project implementation. JSF JPO has requested that Dr. Millar continue his efforts in the role of TPOC for up to six impending SBIR contracts, and assist in program reviews and proposal evaluations.

ADVANCED SENSOR SYSTEMS AND SYSTEM DYNAMIC IDENTIFICATION FOR NAVAL AVIATION SYSTEMS T&E AND HEALTH MANAGEMENT (CBM+)

Richard C. Millar, Associate Professor

Department of Systems Engineering

Sponsor: NAVAIR SBIR Office

OBJECTIVE: The development of technologies enabling enhanced weapon system health management. Two specific objectives addressed by the proposed research are: a) robust sensors for application in extreme environments exposed to high temperature, pressure, vibration, and shock; and b) open system instrumentation/sensor systems reducing the cost and time for weapon system development and qualification test.

SUMMARY: Dr. Millar has been working over the past several years with the Joint Strike Fighter Joint Program Office (JSFJPO) to advance these technologies by proposing SBIR topics, assessing proposals, and as the technical point-of-contact (TPOC) guiding project implementation. JSF JPO has requested that Dr. Millar continue his efforts in the role of TPOC for up to five impending SBIR contracts, plus assisting in the program reviews, proposal evaluations, and planning for these projects. The specifics of the individual SBIR projects are tabulated below.

All five SBIR have completed phase one and were selected for phase two funding continuing into 2011. Phase one options have been exercised in all cases and two of the firms are on contract for phase two, with the others pending.

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PROJECT	CONTRACTOR	DESCRIPTION
General JDF JPO SBIR program technical consultation	Various, as directed.	SBIR phase reviews, proposal evaluations & documentation, technical and transition planning
High Bandwidth Plasma Sensor Suite for Flow, Heat Flux, etc. [SBIR N08-037]	Spectral Energies, LLC (teamed w/GE-Aviation & Notre Dame)	Fundamental technology and demonstration of high frequency plasma/corona based wired & wireless sensors.
High Temperature Sensing Parameters [SBIR N08-037]	Syntronics, LLC (teamed w/Ohio State and UTC)	Fundamental technology and demonstration of Langasite based piezo surface acoustic wave sensor to 1000 deg. C
Thin Film Wireless Temperature Sensor [SBIR N08-004]	Wireless Sensor Technologies, LLC, teamed w/ U. of RI	Fundamental technology and demo of thin film thermocouple sensor w/ wireless signal acquisition to 1000 deg. C.
Plasma Deposited Thin Film Ceramic Thermocouple Sensor [SBIR N08-004]	Engineered Coatings, Inc., teamed w/ SW Research Institute.	Fundamental technology and demonstration of in situ deposition of ceramic T/C sensor on high temperature metal substrates
Intelligent Sensor for Distributed Engine Control for Advanced Propulsion System Application [N07-175]	Embedded Systems LLC	Phase II development of a generic high temperature electronics module for sensors and actuators, enabling distributed control designs.

The successful technologies developed under this research effort are expected to be incorporated into the broader effort described in Dr. Millar's NIFR project summary.

NAVAL AVIATION SYSTEMS ENGINEERING CHALLENGES

Richard C. Millar, Associate Professor
Department of Systems Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: This research addresses several distinct objectives focused on naval-aviation systems-engineering challenges: NAVAIR has identified a general and urgent need to enhance their understanding of, and capabilities in, the performance of systems engineering to improve performance and outcomes in complex system and systems-of-systems acquisition programs. The first objective of the proposed research is to better understand the systems engineering challenges that impede improved acquisition-program performance and outcomes; and to develop systems engineering process and capability enhancements to address these barriers. The second objective is to develop enhanced systems-engineering-based approaches to defining and validating improved weapon system and sub-system health management and maintenance processes and tools. The third objective is to develop and employ systems engineering approaches to define requirements for, and identify effective approaches to, instrumentation and sensor systems and adaptive-model-based control that address significant Naval aviation capability gaps.

NAVAL AVIATION SYSTEMS ENGINEERING CHALLENGES

Richard C. Millar, Associate Professor
Department of Systems Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: The scope of this research initially focused on several Naval aviation systems engineering challenges: a) better understanding the systems engineering challenges that impede improved NAVAIR acquisition program performance and outcomes, and develop systems engineering process and capability enhancements addressing these barriers; b) develop enhanced systems-engineering-based approaches to defining and validating improved weapon system and sub-system health management and maintenance processes and tools; and c) develop and employ systems engineering approaches to define requirements for, and identify effective approaches to, instrumentation and sensor systems and adaptive model-based control that address significant Naval aviation capability gaps.

SUMMARY: NAVAIR has identified a general and urgent need to enhance their understanding of, and capabilities in, the performance of systems engineering to more effectively address Naval Aviation Enterprise objectives. A particular concern is improved performance and outcomes in complex S&T and R&D programs where NAVAIR establishes and leads major system and systems-of-systems acquisition programs in which prime contractors and a host of subcontractors are responsible for the bulk of the work scope. However, as this research effort progressed, it became evident that the application of systems engineering to challenges and opportunities at the sub-system level, and to sustainment processes and related systems of systems, had a more immediate promise of attracting reimbursable funding in the NAVAIR environment.

Two areas within this broad category became the focus of this research: 1) integrated and effective weapon system and sub-system health management and maintenance tools, and processes providing more effective TLCSM (total lifecycle systems management), and 2) open system approaches to instrumentation and sensor systems used in T&E, control systems, and equipment health management,

The sustainment and sub-system architecture challenges were addressed by the application of systems engineering based on Naval-aviation weapon-system capability gaps common to many programs and overarching TLCSM imperatives.

This research agenda was addressed in concert with NAVAIR and key industry players, including small business, major sub-system suppliers, and prime contractors. This effort further identified opportunities for expanded long-term research and demonstration projects under ONR sponsorship.

Under this funding the principal investigator (PI) participated as session chair at the IEEE Aerospace (March) and SAE AeroTech (November) conferences. In June the PI attended the ONR 2009 Advanced Propulsion Review in Monterey, California, to investigate reimbursable research opportunities.

This research effort included participation in several university, industry, and government science and technology forums:

- a) MERS – Military Engine Reliability and Safety. The PI served as action team leader for the government/industry EHM/PHM (engine/propulsion health management) team under the U.S./UK MERS Program Agreement. This is a government/industry forum to define and coordinate future S&T, primarily focused on F-35B STOVL propulsion requirements, anticipating propulsion system testing in 2014. The PI attended and presented at a planning meeting in Arlington, Virginia, on January 30.
- b) Propulsion Instrumentation Working Group (PIWG). With its relevance to anticipated sensor systems research, the PI participated in several leadership teleconferences and attended the PIWG Fall meeting from 5 -6 October.
- c) SAE E-32 Engine Health Management Committee. The PI attended committee meetings in the spring (Switzerland) and fall (Phoenix) and was elected a full member of the committee.
- d) SAE AS-3 Fiber Optic Sensors Group. The PI is monitoring this activity as it relates to a promising option for sensor systems implementation.
- e) Aeronautic Sensors Working Group (ASWG). The PI is a member of this team and participates in their monthly teleconferences.
- f) Distributed Engine Controls Working Group (DECWG). The PI participated in the December meeting of this team, which has an interest in advanced sensor systems, in conjunction with the Propulsion Controls and Diagnostics (PCD) Workshop hosted by NASA Glenn.

PUBLICATIONS:

Millar, R.C., "Defining Requirements for Advanced PHM Technologies for Optimal Reliability Centered Maintenance," *Proceedings of the IEEE Aerospace Conference*, Big Sky, Montana, 8-13 March 2009.

Millar, R.C., "Non-Parametric Statistical Analysis of the Reliability of a Naval Aviation Propulsion System," *Naval Engineers Journal*, Vol. 121, No. 2, 2009.

SYSTEMS ENGINEERING

PROPULSION-SAFETY AND AFFORDABLE-READINESS SENSOR SYSTEMS

Richard C. Millar, Associate Professor
Department of Systems Engineering
Sponsor: Office of Naval Research

OBJECTIVE: Most science and technology (S&T) efforts related to sensors for aerospace system test and evaluation (T&E), health management, and control focus on sensing specific parameters in extreme environments, with some consideration of the issues related to the integration of the sensor into the equipment. The purpose of this research is to undertake a higher-level systems-engineering analysis of requirements and functionality for the integrated sensor systems needed to support the imperative of propulsion safety, affordability, and readiness (PSAR) within the overall goals of total lifecycle systems management (TLCSM). Significant participation by one or two faculty is planned in 2010.

SUMMARY: This project encompasses the need for more cost effective and suitable sensor systems in three categories of sensor application: test and evaluation instrumentation, health management, and system control. A preliminary systems-engineering study has identified requirements that are common to all three applications, but with varying impact and priority. Sensor precision, repeatability, durability, and compatibility with the environment and components to which it is applied are usually addressed in sensor S&T. The proposed research intends to integrate these needs with overall sensor system issues: total instrumentation/sensor system acquisition and lifecycle cost, suitability to the T&E process, and in-service operation, including sustainment, faster and less costly change to address unanticipated instrumentation/sensor requirements, and the desire for open-system interfaces to facilitate timely and cost-effective incorporation of sensor technology advances.

This effort will refine and formalize this initial systems-engineering assessment in consultation with the U.S. Navy and the industry propulsion community to define requirements with quantitative measures, use these to identify and assess potential technological approaches and architectures, and define functional specifications for selected sensor system options. This is expected to be an 18-month effort.

Funding from ONR was received in November 2009, and a draft survey instrument was prepared and reviewed with government and industry and stakeholders at the PIWG and DECWG meetings before the end of the year.

The deliverables from this project are expected to provide direction and assist justification for follow-on integrated instrumentation/sensor systems for propulsion development, test and health management, and control. Preliminary work has inspired a family of SBIR projects addressing key technical hurdles to some of the possible implementations of the basic architectural concept. These are entering phase two and this project will set the stage for phase three efforts starting in FY11. Other opportunities for 6.2 and 6.3 level S&T are also expected to emerge.

It is anticipated that this project may lead to an organic NAVAIR/NPS sensor system laboratory integration and assessment program. This will establish a knowledge-base to support transition to NAVAIR T&E and to general aerospace industry applications.

PROPULSION TURBO-MACHINERY MONITORING

Richard C. Millar, Associate Professor
Department of Systems Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To define requirements for propulsion turbo-machinery monitoring, beyond but encompassing vibration monitoring, in the context of Condition Based Maintenance – Plus (CBM+) and the Propulsion Safety, Affordable Readiness (P-SAR) initiative.

SUMMARY: Existing work on advanced turbo-machinery monitoring has tended to focus on research and development applications and failure-mode specific sensors, although the F-35 Joint Strike Fighter will introduce blade-tip-timing for in-service compressor monitoring, primarily to reduce inspections for foreign object damage (FOD). Little work has been performed looking at the overall problem of propulsion turbo-machinery monitoring while considering the full sustainment needs and constraints in the demanding environment of Naval aviation.

Much S&T effort is being expended on tools to sense the state and usage of individual components, particularly the critical turbo-machinery and typically focused on specific failure modes, as the main line of defense against escalating maintenance costs. A more coordinated and comprehensive systems engineering approach to the problem of turbo-machinery monitoring appears to be needed; the goal is to yield a simpler, robust CBM+ system with the flexibility to deal effectively with unanticipated failure modes.

This project encompasses a systems analysis and functional requirements synthesis focused on total lifecycle systems management (TLCSM), giving full weight to sustainment priorities to yield an integrated CBM+ system architecture for turbo-machinery monitoring that is robust, adaptive, and cost-effective, i.e., suitable for the intended use.

This project was proposed as a nine-month effort. Funding arrived in November 2009, and a meeting was held with the ONR manager before the end of the year.

THE SYSTEMS ENGINEERING PLAN REVIEW FOR THE GLOBAL COMMAND AND CONTROL SYSTEM – MARITIME (GCCS-M) VERSION 4.1

Gregory A. Miller, Lecturer

Edouard Kujawski, Associate Professor

Department of Systems Engineering

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To provide an objective critical review of the draft Systems Engineering Plan (SEP) for the Global Command and Control System - Maritime (GCCS-M), Version 4.1, Acquisition Program.

SUMMARY: Based on current systems engineering best practice in Department of Defense acquisition and current Navy and joint instructions, the Naval Postgraduate School team analyzed the existing draft SEP and provided a report detailing its weaknesses and recommending improvements. Areas examined included connection with the program's acquisition plan and supporting documents and correct tailoring of the SE process itself to include meeting specific requirements for an MS C decision. This effort included meeting with stakeholders at the Space and Naval Warfare Command in San Diego, California. The SEP was reviewed, suggestions for improvement were provided.

“DESIGN DRIFT” – AN INVESTIGATION OF SYSTEMS ENGINEERING LEADING INDICATORS OF ACQUISITION PROJECT SUCCESS

Paul Montgomery, Associate Professor

Ronald R. Carlson, Professor of Practice

Department of Systems Engineering

Sponsor: Naval Postgraduate School Acquisition Research Program

OBJECTIVE: To investigate what systems engineering (SE) metrics and methods can be derived during the development process to generate leading indicators to provide alerts to “design drift” in enough time to remediate before validation failures.

Design drift is the concept where the system design, although coherent with itself, eventually migrates away from the originator user expectations during development. This research proposes to examine how design drift can be measured, quantified, and integrated into SE and acquisition processes. Specifically, the questions to be answered are: can “design drift” be described in community-accepted SE taxonomy? Can integrated requirements-CONOP-architecture metrics be developed that reveal technical health (related to design drift) of a system development? Can the metrics be incorporated into existing SE design and acquisition management methods to provide design drift leading indicators? What new SE methods could be recommended to provide leading indicators to design drift?

THESIS DIRECTED:

Degnan, T., “A Unified Command and Control Architecture for Improved Visualization and Decision-Making on Surface Combatants,” Master’s Thesis, Naval Postgraduate School, December 2010 (expected).

SYSTEMS ENGINEERING

ADVANCED CONCEPTS-OF-OPERATION DEVELOPMENT WITH NORTHROP GRUMMAN

David H. Olwell, Professor
Department of Systems Engineering
Sponsor: Northrop Grumman (CRADA)

OBJECTIVE: To provide technical expertise and support in developing future C4ISR concepts of operation related to the Navy's next-generation surface platforms, whose mission will expand past the current DDG-1000 and focus principally on missile defense and air defense.

ADVANCED OPERATIONAL CONCEPT DEVELOPMENT

David H. Olwell, Professor
Department of Systems Engineering
Sponsor: Northrop Grumman Systems, Inc.

OBJECTIVE: To jointly develop proper concepts of operations (CONOPS) for the Sea Shield and Sea Strike elements of the Navy's Sea Power 21 vision with a focus on expeditionary warfare.

Collaborators will use U.S. Navy documentation and NGES design expertise and input to identify potential technologies and tactics that may enable the achievement of the Sea Power 21 vision. Together the partners will evaluate the ongoing results of the research efforts to incorporate recommended technologies and tactics into individual and, eventually, comprehensive CONOPS recommendations to be shared with U.S. Navy leadership. The overall goal is to produce a broadly studied body of work that will inform the continued development of the actual Sea Power 21 CONOPS with quality information and thought that includes the best of commercial and academic elements.

CREATING A SYSTEMS ENGINEERING BODY-OF-KNOWLEDGE

David H. Olwell, Professor
Department of Systems Engineering
Sponsor: Office of the Secretary of Defense, DDRE

OBJECTIVE: To contribute to a systems engineering (SE), community effort to establish an authoritative body of knowledge (BoK) in SE and to establish a broad, consensus-based, reference curriculum for an SE Master's degree based, in part, on that BoK.

Improvements in the Department of Defense (DoD) SE workforce depend, in part, on having a foundation of community-accepted SE knowledge on which competencies, education, and professional certification are based. The existing SE BoK available through INCOSE is currently the most authoritative available, but is widely acknowledged within INCOSE as being incomplete and dated. (The current INCOSE BoK was released in 2003 and is available at <http://g2sebok.incose.org/>. There have been no substantive improvements in it since then.) A major effort to create a mature, robust BoK is necessary to support systems of systems, large-scale network-centric systems, agile development, and other facets of modern development and modern systems that are essential for the DoD and intelligence communities. This community research effort will establish that updated BoK with the active involvement of INCOSE and others in the SE community and encourage and enable the broad adoption of that BoK. Faculty participating include a few from the Naval Postgraduate School and 31 others off-campus.

PUBLICATION:

Squires, A., Pyster, A., Olwell, D., Few, S., and Gelosh, D., "Announcing BKCASE: Body of Knowledge and Curriculum to Advance Systems Engineering," *Insight*, Vol. 12, No. 4, December 2009.

SYSTEMS ENGINEERING

EDUCATING THE ACQUISITION WORKFORCE

David H. Olwell, Professor

Department of Systems Engineering

Sponsor: Navy Modeling and Simulation Office, Defense Modeling and Simulation Office

OBJECTIVE: To develop requirements and architecture for an educational program to educate users of modeling and simulation (M&S) in how to effectively request and incorporate M&S into acquisition activities. Naval Postgraduate School faculty participating include Olwell, Paulo, Few, Shin, Darken, Papoulas, Chu, Gordis, Kwon, Yakimenko, Dutta, Kolar, and Lloyd, and another dozen at ODU, JHU/APL, UAH, UCSD, GMU, and UCF.

CONFERENCE PUBLICATION:

Olwell, D.H., "New M&S Education Opportunities: How to Help Your Users be Smarter Customers of M&S," *National Defense Industry Association Modeling and Simulation Conference*, February 2009.

TECHNICAL REPORT:

Olwell, D.H., Johnson, J.M., Didoszak, J.M., and Few, S.M., "Modeling and Simulation Education for the Acquisition and T&E Workforce: Final Report," Naval Postgraduate School Technical Report, NPS-SE-09-012, 2009.

EDUCATING THE ACQUISITION AND TEST WORKFORCE: WORKFORCE MODELING AND SIMULATION EDUCATION AND TRAINING FOR LIFELONG LEARNING

David H. Olwell, Professor

Department of Systems Engineering

Sponsor: Defense Modeling and Simulation Office

OBJECTIVE: Modeling and simulation (M&S) is an essential capability for managing risk, reducing time and cost for acquisition. Currently, there is no unified approach for determining which M&S tools to use, when to use them, or how to use them across the development lifecycle. Additionally, a range of training options are needed to improve multi-service community members' capabilities to select and use M&S tools effectively and efficiently. These include initial education and training, refresher training, continuing education, etc.

ENERGY CONSUMPTION AND EFFICIENCY IN THE NAVY

David H. Olwell, Professor

Department of Systems Engineering

Sponsor: Office of Naval Research

OBJECTIVE: To develop a strategy and work-plan to model Navy ashore energy consumption as a function of policy variables and funds. Students participating will include SI0810-311-0912, and faculty participating will include Olwell, Calvano, Shebalin, and Harney.

AN EVALUATION OF ENERGY CONSUMPTION AND ENERGY EFFICIENCY IN THE NAVY

David H. Olwell, Professor

Department of Systems Engineering

Sponsor: Office of Naval Research

OBJECTIVE: To devise a systems-approach-based plan for future development of a model-based methodology to evaluate energy consumption and identify technology insertion opportunities and infrastructure modifications to improve energy efficiency in a variety of Navy applications, afloat and ashore.

SYSTEMS ENGINEERING

A CASE STUDY OF DISTANCE EDUCATION AT THE NAVAL POSTGRADUATE SCHOOL

Walter E. Owen, Senior Lecturer
Department of Systems Engineering
Benjamin J. Roberts, Senior Lecturer
Graduate School of Business and Public Policy
Sponsor: Naval Postgraduate School

OBJECTIVE: To assess video tele-education as an instructional delivery mode.

SUMMARY: This study investigated video tele-education as an effective instructional delivery mode for three graduate degree programs at the Naval Postgraduate School (NPS). The study measured faculty attitudes, student attitudes, and administrative staff attitudes. A quasi-experimental case study comparing two delivery methods, resident and tele-education, was conducted. Data for student attitudes were obtained by archival student opinion forms used by NPS. Data for faculty and administrative staff attitudes were obtained from online surveys. Follow-up personal interviews were conducted as required to clarify respondent answers. Faculty, student, and administrative staff attitudes were measured comparing instruction delivered by distance learning mode using video tele-education and traditional mode using the standard resident classroom. Qualitative and quantitative methods were used for analysis. The case study provides NPS and other academic institutions valuable lessons to help build or improve their distance education programs.

PRESENTATION:

This study was presented at the World Conference on Educational Multimedia, Hypermedia, and Telecommunications (ED-Media 2009) in June 2009.

CHALLENGES IN DISTANCE-LEARNING PROGRAM DEVELOPMENT AND DELIVERY

Walter E. Owen, Senior Lecturer
Department of Systems Engineering
Benjamin J. Roberts, Senior Lecturer
Graduate School of Business and Public Policy
Sponsor: Naval Postgraduate School

OBJECTIVE: To analyze distance-learning program development approaches.

SUMMARY: This report concentrated on two graduate systems engineering programs that were delivered by multiple configurations of blended approaches to distributed education. The authors have served as program managers for these programs and have gathered lessons learned over a ten-year time period. The reason this is a unique account is that, within the Department of Defense, many regulations and safeguards are employed for security reasons, presenting challenges to what would otherwise be a model delivery system. To meet these challenges, program managers developed blended strategies that included different configurations of web conferencing, online instruction, embedded faculty, and onsite faculty visits, in addition to an already established video tele-education approach. Overall, this has been an innovative and successful approach. The programs are highly sought after within the Defense Department, and it has been a challenge to meet the demand.

PRESENTATION:

This report was accepted in November 2009 and presented at the 8th International Conference on Education, January 2010.

SYSTEMS ENGINEERING

UNIQUE STRATEGIES AND TECHNOLOGICAL SOLUTIONS FOR SYSTEMS ENGINEERING DISTANCE EDUCATION

Walter E. Owen, Senior Lecturer
Department of Systems Engineering
Benjamin J. Roberts, Senior Lecturer
Graduate School of Business and Public Policy
Sponsor: Naval Postgraduate School

OBJECTIVE: To assess strategies for providing distance learning programs in systems engineering.

SUMMARY: This report concentrated on strategies employed when graduate systems engineering programs are delivered by multiple configurations of blended approaches to distributed education. The authors have served as program managers for these programs and have gathered lessons learned over a ten-year time period. The strategies had to consider Department of Defense regulations and safeguards that are employed for security reasons, presenting challenges to what would otherwise be a model delivery system. To meet these challenges, program managers developed blended strategies that included different configurations of web conferencing, online instruction, embedded faculty, and onsite faculty visits, in addition to an already established video tele-education approach. The strategies were employed in a contingent manner, influenced by student dispersion and resources at the student site.

PRESENTATION:

This report was presented at the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education in November 2009.

AUTONOMOUS AMPHIBIOUS ROBOTS FOR SURF ZONE OPERATIONS

Ravi Vaidyanathan, Assistant Professor
Department of Systems Engineering
Sponsor: National University of Singapore

OBJECTIVE: To develop a prototype autonomous amphibious robot for maritime surf-zone operations. Year one (2008-09) will focus on assessment of performance characteristics, insect-inspired robot design, and simulation of performance. Year two will focus on fabrication and control system design and implementation.

SUMMARY: In 2009, the completion of the design and simulation of an autonomous amphibious robot, Pelican Whegs™, was completed. The robot was designed to be capable of navigating the challenging terrain of the ocean surf-zone region based on abstracted biological inspiration. Several design innovations, particularly an articulated body/tail section of the robot, were developed that will enable Pelican Whegs™ to navigate on rough terrain on land and underwater, to accomplish tasks with little or no low-level control. Specific program accomplishments in year one of the program included: survey of work in the field; assessment of low-level robot performance considerations; completion of insect-inspired design of an amphibious vehicle, including a tail component to enhance terrestrial locomotion and enable swimming movement; and implementation of a performance simulation of amphibious robot, including an analysis of tail augmentation during terrestrial and aquatic locomotion. All planned objectives for the first year of the program have been met.

PUBLICATION:

Boxerbaum, A., Dunbar, T., Bachmann, R.J., Harkins, R., Quinn, R.D., Burgess, S.C., and Vaidyanathan, R., "Design and Testing of a Highly Mobile Insect-Inspired Autonomous Robot in a Beach Environment," *International Journal of Design and Nature*, 2010 (accepted).

SYSTEMS ENGINEERING

CONFERENCE PUBLICATIONS:

Boxerbaum, A., Klien, M., Quinn, R.D., Harkins, R., and Vaidyanathan, R., "Design of a Semi-Autonomous Amphibious Surf-Zone Robot," *IEEE/ASME Conference on Advanced Intelligent Mechatronics (AIM)*, pp. 974-979, Singapore, July 2009.

Harkins, R., Dunbar, T., Boxerbaum, A.S., Bachmann, R.J., Vaidyanathan, R., and Quinn, R.D., "An Autonomous Highly Mobile Robot in a Beach Environment," *Proceedings of the International Conference on Intelligent Automation and Robotics (ICIAR '08)*, pp. 613-618, San Francisco, California, October 2008. (Paper submitted prior to program start, updated based on initial studies.)

PRESENTATION:

Vaidyanathan, R., "Design Challenges for an Autonomous Amphibious Surf-Zone Robot," Critical Impediments and Future Challenges for Multi-Modal Robotic Locomotion Workshop, IEEE International Conference on Intelligent Robots and Systems, 15 October 2009 (invited).

BOOK CHAPTER:

Harkins, R., Dunbar, T., Boxerbaum, A.S., Bachmann, R.J., Quinn, R.D., Burgess, S.C., and Vaidyanathan, R., "Confluence of Active and Passive Control Mechanisms Enabling Autonomy and Terrain Adaptability for Robots in Variable Environments," *IAENG Transactions on Electrical Engineering - Special Edition of the 2008 World Congress on Engineering and Computer Science*, C. Douglas, W. Grundfest, and L. Schruben (Eds.), 12 pp., IEEE Press (forthcoming).

AWARD:

Certificate of Merit (Finalist for Best Paper in Conference), "Design and Testing of an Autonomous Robot in a Beach Environment," International Conference on Intelligent Automation and Robotics, (one of three finalists out of approximately 100 robotics papers (660 total at conference)), San Francisco, California, December 2008.

ADVANCED POWER SYSTEM MODEL-BASED ARCHITECTURE AND DESIGN METHODS

Clifford Whitcomb, Associate Professor

Department of Systems Engineering

Sponsor: U.S. Navy Office of Naval Research

OBJECTIVE: To develop a functionally integrated architecture and design simulation environment to implement automated methods for exploring different electrical-distribution-system tradeoffs in a total ship context in order to find optimum ship designs in terms of operational effectiveness metrics.

SUMMARY: This work was combined with the other Office of Naval Research (ONR)-funded project on power system architectures. The work focused on the integration of electric weapons and advanced combat systems into all electric ship architectures. The development of the TESLA ship for the TSSE project contains the ship design result. An electric plant availability simulation was developed and conducted to determine ship operational impacts using a reliability software model. A notional warfighting scenario was developed in the Phoenix tool being developed with Professor Auguston in the Naval Postgraduate School Department of Computer Science.

THESES DIRECTED:

Lemerande, T., 311 MSSE DL (projected graduation 2010).

Worked with the 2009 TSSE Ship Design Project "TESLA (Total Electric Ship - Long-Range Armament)."

SYSTEMS ENGINEERING

THE DESIGN OF ADVANCED POWER SYSTEMS FOR WAR-FIGHTING EFFECTIVENESS

Clifford Whitcomb, Associate Professor
Department of Systems Engineering
Sponsor: U.S. Navy Office of Naval Research

OBJECTIVE: To develop a functionally integrated architecture and design simulation environment to implement methods for exploring different electrical-distribution-system tradeoffs in a total ship context in order to find optimum ship designs in terms of operational effectiveness metrics.

SUMMARY: This work was combined with the other Office of Naval Research-funded project on power system architectures. The work focused on the integration of electric weapons and advanced combat systems into all electric ship architectures. The development of the TESLA ship for the TSSE project contains the ship design result. An electric plant availability simulation was developed and conducted to determine ship operational impacts using a reliability software model. A notional warfighting scenario was developed in the Phoenix tool being developed with Professor Auguston in the Naval Postgraduate School Department of Computer Science.

THESES DIRECTED:

Choi, H., "Naval Ship Concept Design in the Republic of Korea Navy: A Systems Engineering Approach," Master's Thesis, Naval Postgraduate School, September 2009.

Lemerande, T., 311 MSSE DL (projected graduation 2010).

Worked with the 2009 TSSE Ship Design Project "TESLA (Total Electric Ship - Long-Range Armament)."

UNMANNED VEHICLE *SENTRY* SYSTEM-OF-SYSTEMS ARCHITECTURE SUPPORT AND DEVELOPMENT

Clifford Whitcomb, Associate Professor
Department of Systems Engineering
Sponsor: U.S. Navy Office of Naval Research

OBJECTIVE: To study the unmanned vehicle (UV) *Sentry* system-of-systems (SoS) architecting process and architecture framework that implements various surface, sub-surface, and airborne UV to accomplish the desired *UV SENTRY* capabilities; and to attend meetings in support of the unmanned vehicle *SENTRY* systems architecture study.

SUMMARY: Developed various portions of OPSIT architecture models in CORE; developed a subsystem trade-off and optimization method, including uncertainty analysis for the impact of the mission need on the autonomous surface vessel; and worked with *UV SENTRY* team members to create a risk assessment program.

PUBLICATIONS:

Whitcomb, C., Hlavin, W., Southworth, J., and Addington, C., "Model-Based Methodology for System-of-Systems Engineering with Application to the Development of the Architecture for the Unmanned Vehicle *Sentry*," *ASNE Annual Symposium*, 2009.

Whitcomb, C., Hlavin, W., Southworth, J., and Addington, C., "Model-Based Systems Engineering Approach to U.S. Navy Towing and Salvage Fleet Recapitalization," *Towing and Salvage Symposium*, *ASNE*, 2009.

PRESENTATIONS:

Presented papers at two ASNE conferences.

Presented to *UV SENTRY* project review meetings.

THESIS DIRECTED:

Letourneau, J., “Incorporating Multicriteria Optimization and Uncertainty Analysis in the Model-Based Systems Engineering of an Autonomous Surface Craft,” Master’s Thesis, Naval Postgraduate School, September 2009.

DEPARTMENT OF SYSTEMS ENGINEERING

**2009
Faculty Publications
and Presentations**

JOURNALS

Bachmann, R.J., Boria, F., Vaidyanathan, R., Ifju, P., and Quinn, R.D., "A Biologically-Inspired Micro Sensor Platform Capable of Aerial and Terrestrial Locomotion," *Mechanism and Machine Theory (MMT)*, 44, pp. 512-526, 2009.

Boxerbaum, A., Bachmann, R.J., Harkins, R., Quinn, R.D., Burgess, S.C., and Vaidyanathan, R., "Design, Testing, and Control of a Highly Mobile Insect-Inspired Autonomous Robot in a Beach Environment," *International Journal of Design and Nature*, 4, 4, pp. 1-18, 2009.

Brown, G., Carlyle, M., Harney, R., Skroch, E., and Wood, K., "Interdicting a Nuclear Weapons Project," *Operations Research*, Vol. 57, No. 4, pp. 866-877, July-August 2009.

Harney, R.C., "Inaccurate Prediction of Nuclear Weapons Effects and Possible Adverse Influences on Nuclear Terrorism Preparedness," *Homeland Security Affairs*, Vol. V, No. 3, September 2009.

Keane, B., Fireman, H., Hough, J., Helgersen, D., and Whitcomb, C., "Ready to Design a Naval Ship? – Prove It!" *Journal of Ship Production*, Society of Naval Architects and Marine Engineers (SNAME), 2009.

Kota, S., Gupta, L., Molfese, D., and Vaidyanathan, R., "A Dynamic Channel Selection Strategy for Dense Array Event Related Potential (ERP) Classification," *IEEE Transactions on Biomedical Engineering*, 56, 4, pp. 1040-1051, 2009.

Mace, M., Vaidyanathan, R., Wang, S., and Gupta, L., "Tongue in Cheek: A Novel Concept in Assistive Human-Machine Interface," *Journal of Assistive Technologies*, 3, 3, pp. 14-26, 2009.

Menzies, T., Williams, S., Elrawas, O., Baker, D., Boehm, B., Hihn, J., et al., "Accurate Estimates without Local Data," *Software Process Improvement and Practice*, Vol. 14, 2009.

Millar, R.C., Mazzuchi, T.A., and Sarkani, S., "Non-Parametric Statistical Analysis of the Reliability of a Naval Aviation Propulsion System," *Naval Engineers Journal*, Vol. 121, No. 2, 2009.

Psallidas, K., Hootman, J.C., and Whitcomb, C.A., "Forecasting System Level Impacts of Technology Infusion in Ship Design," *Naval Engineers Journal*, Vol. 122, No. 1, 2010.

Psallidas, K., Hootman, J.C., and Whitcomb, C.A., "Theater Level Impacts of Advanced Air Independent Propulsion Systems on Conventional Submarines," *Naval Engineers Journal*, Vol. 122, No. 1, 2010.

Squires, A., Pyster, A., Olwell, D., Few, S., and Gelosh, D., "Announcing BKCASE: Body of Knowledge and Curriculum to Advance Systems Engineering," *Insight*, Vol. 12, No. 4, December 2009.

CONFERENCE PUBLICATIONS

Bachman, R., Vaidyanathan, R., and Quinn, R.D., "Drive Train Design Enabling Locomotion Transition of a Small Hybrid Air-Land Vehicle," *IEEE International Conference on Intelligent Robots and Systems (IROS)*, pp. 5647-5642, St. Louis, Missouri, October 2009.

Boxerbaum, A., Klien, M., Quinn, R.D., Harkins, R., and Vaidyanathan, R., "Design of a Semi-Autonomous Amphibious Surf-Zone Robot," *IEEE/ASME Conference on Advanced Intelligent Mechatronics (AIM)*, pp. 974-979, Singapore, July 2009.

Burgess, S.C., Ling, C.S., Conn, A., Araromi, S., Wang, J., and Vaidyanathan, R., "Development of a Novel Electro Active Polymer (EAP) Actuator for Driving the Wings of Flapping Micro Air Vehicle," *Eleventh International Conference on Optimum Design of Structures and Materials in Engineering*, 11 pp., Algarve, Portugal, June 2009.

Goshorn, D., Goshorn, R., Goshorn, J., and Goshorn, L., "Abnormal Behavior Classification and Alerting through Detection, Identification, Prediction, and Reaction (DIPR) System Applied to a Multi-Camera Network," *German Conference on Artificial Intelligence*, Workshop on Behavior Monitoring and Interpretation, September 2009.

Green, J.M. and MSSE Cohort 6, "Application of Model-Based Systems Engineering Methods to Development of Combat System Architectures," *Proceedings of the 6th Annual Research Symposium at NPS*, NPS-AM-09-025, 2009.

Kota, S., Mace, M., Gupta, L., and Vaidyanathan, R., "A DCT-Gaussian Classification Scheme for Human Robot Interface," *IEEE International Conference on Intelligent Robots and Systems (IROS)*, pp. 5503-5508, St. Louis, Missouri, October 2009.

Langford, G., "Foundations of Value Based Gap Analysis: Commercial and Military Developments," *Proceedings of the 19th Annual International Symposium of INCOSE and the Third Asia-Pacific Conference on Systems Engineering*, Singapore, 20-23 July 2009.

Langford, G., "Product Upgrades Based on Minimum Expected Quality Loss," *Proceedings of the 19th Annual International Symposium of INCOSE and the Third Asia-Pacific Conference on Systems Engineering*, Singapore, 20-23 July 2009.

Langford, G. and de Souza, R., "Becoming a Systems Engineer," *Proceedings of the 19th Annual International Symposium of INCOSE and the Third Asia-Pacific Conference on Systems Engineering*, Singapore, 20-23 July 2009.

Lock, R.J., Vaidyanathan, R., Burgess, S.C., and Quinn, R.D., "Impact of Passive Stiffness Variation on Stability and Mobility of a Hexapod Robot," *IEEE/ASME Conference on Advanced Intelligent Mechatronics (AIM)*, pp. 980-986, Singapore, July 2009.

Ma, Z., Krings, A.W., and Millar, R.C., "Introduction of First Passage Time (FPT) Analysis for Software Reliability and Network Security," *CSIRW '09: Proceedings of the 5th Annual Workshop on Cyber Security and Information Intelligence Research: Cyber Security and Information Intelligence Challenges and Strategies*, April 2009 (available in the ACM Digital Library).

Mamun, K.M., Vaidyanathan, R., and Wang, S., "Bayesian Classification of Tongue Movement," *INSPIRE 2009*, Imperial College London, 4 pp., London, United Kingdom, September 2009.

Mamun K.M., Mace, M., Lutmen, M.E., Vaidyanathan, R., and Wang, S., "Pattern Classification of Tongue Movement Ear Pressure Signal Based on Wavelet Packet Feature Extraction," *PGBioMed 2009*, 4 pp., Magdalen College, Oxford University, United Kingdom, July 2009.

Millar, R.C., "Defining Requirements for Advanced PHM Technologies for Optimal Reliability Centered Maintenance," *Proceedings of the IEEE Aerospace Conference*, Big Sky, Montana, 8-13 March 2009.

Millar, R.C., "Failure Prevention for System Availability," *Proceedings of the Machinery Failure Prevention Technology Conference*, Virginia Beach, Virginia, 6-8 May 2008.

Millar, R.C., "The Use of Non-Parametric Statistical Tools to Assess Reliability and Availability Drivers," *Proceedings of the Machinery Failure Prevention Technology Conference*, Virginia Beach, Virginia, 6-8 May 2008.

Osmundson, J., Langford, G., and Huynh, T., "Emergent Behaviour in an Unregulated Financial System of Systems: Economic Meltdown," *Proceedings of the 19th Annual International Symposium of INCOSE and the Third Asia-Pacific Conference on Systems Engineering*, Singapore, 20-23 July 2009.

Owen, W. and Roberts, B., "A Case Study of Distance Education at the Naval Postgraduate School," *World Conference on Educational Multimedia, Hypermedia, and Telecommunications*, 2654-2659, 2009.

Roberts, B. and Owen, W., "Challenges in Distance Learning Program Development and Delivery," *Proceedings of the 8th Annual Hawaii International Conference on Education 2010*, pp. 2735-2740, Honolulu, Hawaii, 2009.

Roberts, B. and Owen, W., "Unique Strategies and Technological Solutions for Systems Engineering Distance Education," *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2009*, T. Bastiaens, et al. (Eds.), pp. 1890-1895, Vancouver, B.C., 2009.

Vanatta, N., Miller, G.A., and Goshorn, R.E., "A Method to Analyze Network-Centric Capabilities for Agile C2 for Combat Support Soldiers in Southwest Asia," *14th International Command and Control Research and Technology Symposium (ICCRTS)*, Washington, D.C., 15-17 June 2009.

Wang, Q., Garousi, V., Madachy, R., and Pfahl D. (Eds.), "Trustworthy Software Development Processes: International Conference on Software Process," *ICSP 2009*, Vancouver, Canada, 2009.

Whitcomb, C., Hlavin, W., Southworth, J., and Addington, C., "Model-Based Methodology for System of Systems Engineering with Application to the Development of the Architecture for the Unmanned Vehicle Sentry," *ASNE Annual Symposium*, 2009.

Whitcomb, C., Hlavin, W., Southworth, J., and Addington, C., "Model-Based Systems Engineering Approach to U.S. Navy Towing and Salvage Fleet Recapitalization," *Towing and Salvage Symposium*, ASNE, 2009.

PRESENTATIONS

Fortune, J. and Madachy, R., "COSYSMO Workshop," 24th International Forum on COCOMO and Systems/Software Cost Modeling, Cambridge, Massachusetts, 2009 (workshop lead).

Goshorn, R.E., "Distribution of Intelligent Ad-Hoc Satellite Nodes-A Paradigm Shift in Space (Network-Centric Systems of Systems)," National Reconnaissance Office Systems Engineering Conference, 4 August 2009.

Goshorn, D. and Goshorn, R., "Cybersecurity in a Smart Environment – Network Centric Systems," Cybersecurity Conference, Monterey, California, Fall 2009.

Johnson, J. and Blais, C., "Ontology-Based Solutions for Software Reuse," 6th Annual Acquisition Research Symposium, Monterey, California, 13-14 May 2009.

Langford, G., "Foundations of Value Based Gap Analysis: Commercial and Military Developments," 19th Annual International Symposium of INCOSE and the Third Asia-Pacific Conference on Systems Engineering, Singapore, 20-23 July 2009.

Langford, G., "Product Upgrades Based on Minimum Expected Quality Loss," 19th Annual International Symposium of INCOSE and the Third Asia-Pacific Conference on Systems Engineering, Singapore, 20-23 July 2009.

Langford, G., "Systems Engineering Design and Architectures for Command and for Control: A Short Course," March 2009.

Madachy, R., "Integrated COCOMO Suite Tool for Education," 24th International Forum on COCOMO and Systems/Software Cost Modeling, Cambridge, Massachusetts, 2009.

SYSTEMS ENGINEERING

Madachy, R. and Clark, B., “Metrics Unification and Productivity Domains Workshop,” 24th International Forum on COCOMO and Systems/Software Cost Modeling, Cambridge, Massachusetts, 2009 (workshop lead).

Madachy, R. and Valerdi, R., “Risk Analysis and Mitigation with Expert COSYSMO,” 24th International Forum on COCOMO and Systems/Software Cost Modeling, Cambridge, Massachusetts, 2009.

Madachy, R., Boehm, B., Clark, B., Reifer, D., and Rosa, W., “A Sizing Framework for DoD Software Cost Analysis,” 24th International Forum on COCOMO and Systems/Software Cost Modeling, Cambridge, Massachusetts, 2009.

Millar, R.C., “Engineering Challenges in Propulsion Systems/Airframe Integration,” SAE 2009 AeroTech Congress and Exhibition, Seattle, Washington, 10-12 November 2009.

Moya, L., Crutchfield, A., and Johnson, J., “Best Practices in M&S,” ITEA Live-Virtual-Constructive Conference, El Paso, Texas, 12-15 January 2009.

Olwell, D.H., “New M&S Education Opportunities: How to Help Your Users be Smarter Customers of M&S,” National Defense Industry Association Modeling and Simulation Conference, February 2009.

Olwell, D.H., “Selecting the Correct Accelerated Life Model,” International Applied Reliability Symposium, Barcelona, Spain, 2009.

Olwell, D.H., “Selecting the Correct Accelerated Life Model,” International Applied Reliability Symposium, San Diego, California, 2009.

Olwell, D.H., “What is the Nature of SE Competence for Individual Defence Employees as Well as the Defence Workforce as a Whole?” INCOSE International Symposium Academic Forum, Singapore, 2009 (invited presentation).

Rosa, W., Clark, B., Madachy, R., Reifer D., and Boehm, B., “Software Cost Metrics Manual,” 42nd Department of Defense Cost Analysis Symposium, Williamsburg, Virginia, 2009.

Vaidyanathan, R., “Critical Impediments and Future Challenges for Multi-Modal Robotic Locomotion,” Plenary Opening Talk, 2009 IEEE International Conference on Intelligent Robots and System Workshop on Multi-Modal Robotic Locomotion Systems, October 2009.

CONTRIBUTIONS TO BOOKS

Bachmann, R.J., Vaidyanathan, R., Ifju, P.G., and Quinn, R.D., “Powered Flight and Walking Integrated in a Miniature Vehicle for Aerial and Terrestrial Mobility,” Chapter 18 in *Flying Insects and Robots*, D. Floreano, J. Zufferey, M. Srinivasan, and C. Ellington (Eds.), pp. 247-271, Springer Verlag Press, ISBN: 978-3-540-000, 2009.

Goshorn, R.E., Goshorn, D.E., Goshorn, J.L., and Goshorn, L.A., “Behavior Modeling for Detection, Identification, Prediction, and Reaction (DIPR) in AI Systems Solutions,” *Handbook of Ambient Intelligence and Smart Environments*, Springer U.S., pp. 669-700, 1 October 2009.

Harkins, R., Dunbar, T., Boxerbaum, A.S., Bachmann, R.J., Quinn, R.D., Burgess S.C., and Vaidyanathan, R., “Confluence of Active and Passive Control Mechanisms Enabling Autonomy and Terrain Adaptability for Robots in Variable Environments,” *IAENG Transactions on Electrical and Electronics Engineering Volume I*, C. Douglas, W. Grundfest., and L. Schruben (Eds.), pp. 138-149, IEEE Press, ISBN 978-1-4244-3545-6, 2009.

SYSTEMS ENGINEERING

Petkov, D., Edgar-Nevill, D., Madachy, R., and O'Connor, R., "Information Systems, Software Engineering, and Systems Thinking: Challenges and Opportunities," *Strategic Information Systems: Concepts, Methodologies, Tools, and Applications*, M. Gordon Hunter (Ed.), 2009

INTERVIEWS

Goshorn, R., "A.I. in the Enterprise," Forbes.com one-on-one interview with by Ed Sperling, 16 March 2009. (<http://www.forbes.com/2009/03/14/artificial-intelligence-enterprise-technology-cio-network-artificial-intelligence.html>.)

Goshorn, R., "Artificial Intelligence: This Time It's For Real," interview conducted by E. Sperling, Editor in Chief of *System Level Design Community*. (<http://chipdesignmag.com/sld/blog/2008/12/29/artificial-intelligence-this-time-its-for-real/>.)

TECHNICAL REPORTS

Hughes, W.P. (with contributions by Kline, J., Otte, D., Calvano, C., Nussbaum, D., Twomey, C., Langford, G., Burton, D., and Franck, C.), "The New Navy Fighting Machine: A Study of the Connections between Contemporary Policy, Strategy, Sea Power, Naval Operations, and the Composition of the United States Fleet," Naval Postgraduate School Technical Report, NPS-OR-09-002, August 2009.

Langford, G., "United States Navy Phase 0 Operations and Country Stability," Naval Postgraduate School Technical Report, NPS-SE-09-011, 19 October 2009.

Langford, G. and Huynh, T., "Cocaine Tunnel Threat Assessment," Naval Postgraduate School Technical Report, NPS-SE-09-010, 30 September 2009.

Olwell, D., Johnson, J., Didoszak, J., and Few, S., "Modeling and Simulation Education for the Acquisition and T&E Workforce: Final Report," Naval Postgraduate School Technical Report, NPS-SE-09-012, September 2009.

**SPACE SYSTEMS
ACADEMIC GROUP**

**RUDOLF PANHOLZER
CHAIRMAN**

SPACE SYSTEMS ACADEMIC GROUP

OVERVIEW:

The Space Systems Academic Group (SSAG), along with ten academic departments, is an integral part of the Graduate School of Engineering and Applied Sciences. As an interdisciplinary association of professors, the SSAG provides direction and guidance for two curricula: Space Systems Engineering and Space Systems Operations. Officer students in the Space Systems curricula fulfill degree requirements for a Master of Science in the department of their choice or in a specialized engineering science. A space-oriented thesis is mandatory, as is course work to fulfill the requirements of a space billet. Officer graduates are prepared to manage the technical aspects of a space-system lifecycle, including design, development, installation, and maintenance of spacecraft, space payloads, supporting ground stations, terminals, and C3 connectivity. The SSAG serves as the focal point for all space-related research performed at the Naval Postgraduate School (NPS). A major goal is to couple NPS space-research efforts with the graduate education of military officers. This is typically accomplished through space-related thesis research in several areas and includes small satellite projects created specifically as an educational tool for officer students. The SSAG oversees classified and unclassified student involvement in research activities and helps facilitate their placement in follow-on tours.

CURRICULA SERVED:

- Space Systems Operations
- Space Systems Engineering

DEGREES GRANTED:

- Master of Science in Space Systems Operations
- Master of Science in Aerospace Engineering
- Master of Science in Electrical Engineering
- Master of Science in Mechanical and Aerospace Engineering
- Master of Science in Applied Physics

RESEARCH THRUSTS:

- Military Applications for Space
- Space Reconnaissance and Remote Sensing
- Radiation Hardened Electronics for Space
- Design, Construction, and Launching of Small Satellites
- Classified (SCI Level) Research
- Satellite Communications Systems
- Military Space Systems and Architectures

RESEARCH CHAIRS:

- Navy Space Technology Program Chair
- NNSOC Academic Chair
- NASA Chair
- National Reconnaissance Office Chair
- NSS Engineering and Acquisition Chair
- MASINT Chair

SPACE SYSTEMS ACADEMIC GROUP

RESEARCH CENTERS:

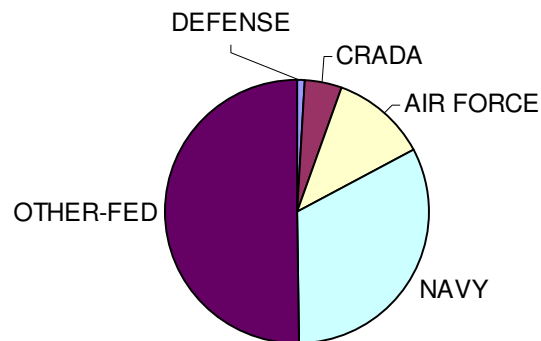
- Spacecraft Research and Design Center
- Center for Reconnaissance Research
- Center for Radiation Hardened Electronics
- Center for Cryptologic Research

RESEARCH FACILITIES:

- Open Site EMI/EMC Facility
- Satellite Ground Station Facility
- FLTSATCOM Satellite Operations
- Spacecraft Attitude Dynamics and Control Laboratory
- Spacecraft Environmental Simulation and Test Laboratory
- Radiation Effects Laboratory
- Solar Simulation Facility
- NPS-AFRL Optical Relay Spacecraft Laboratory
- Flash X-Ray Facility
- Small Satellite Test and Development Laboratory
- Smart Structures Laboratory

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Space Systems Academic Group is provided below:



Size of Program: \$1.4M

SPACE SYSTEMS ACADEMIC GROUP

Rudolf Panholzer
Professor and Chair
831-656-2154
rpanholzer@nps.edu

Terry Alfried
Visiting Professor
831-656-3929
ktalfrie@nps.edu

Tom Betterton
Space Technology Chair
tcbetter@nps.edu

Daniel C. Boger
Chairman, Department of
Information Sciences
831-656-3671
dboger@nps.edu

Alexander Bordetsky
Associate Professor
Department of Information
Sciences
831-656-2287
abordets@nps.edu

Christopher M. Brophy
Associate Professor
Department of Mechanical and
Aerospace Engineering
831-656-2327
cmbrophy@nps.edu

Nancy Ann Budden
Department of Defense Analysis
831-656-3332
nbudden@nps.edu

Daniel W. Bursch
CAPT, USN (Ret.)
National Reconnaissance Office
Aerospace Chair Professor
831-656-2764
dwbursch@nps.edu

William B. Colson
Distinguished Professor
Department of Physics
831-656-2765
colson@nps.edu

Donald A. Danielson
Professor, Department of
Applied Mathematics
831-656-2622
dad@nps.edu

Philip A. Durkee
Professor and Chair
Department of Meteorology
831-656-2516
durkee@nps.edu

Douglas J. Fouts
Professor and Associate Dean of
Research, Department of
Electrical and Computer
Engineering
831-656-2852
fouts@nps.edu

James Horning
Research Associate
831-656-3199
jahornin@nps.edu

Mathias N. Kolsch
Assistant Professor
Department of Computer
Science
831-656-3402
kolsch@nps.edu

Barry S. Leonard
Visiting Associate Professor
Department of Mechanical and
Aerospace Engineering
bleonard@nps.edu

Herschel H. Loomis
Professor
Department of Electrical and
Computer Engineering
831-656-3214
loomis@nps.edu

Sherif N. Michael
Professor, Department of
Electrical and Computer
Engineering
831-656-2252
michael@nps.edu

James C. Moltz
Associate Professor
Department of National Security
Affairs
jcmoltz@nps.edu

Jim Mueller
Navy TENCAP Research
Coordinator
Space Systems Academic Group
831-656-3549
jwmuelle@nps.edu

Beny Neta
Professor, Department of
Applied Mathematics
831-656-2235
bneta@nps.edu

James H. Newman
Professor
831-656-2487
jhnewman@nps.edu

Richard C. Olsen
Professor
Department of Physics
831-656-2019
olsen@nps.edu

John Phillips
Smith/McCool NASA Chair
Professor
831-656-7844
jlphilli@nps.edu

SPACE SYSTEMS ACADEMIC GROUP

Randall “Ty” Pollak
Lt Col, USAF, Military Faculty
Assistant Professor
831-656-1144
randall.pollak@us.af.mil

Charles M. Racoosin
Visiting Assistant Professor and
Space Systems Academic Chair
831-656-2231
cmracoos@nps.edu

Mark M. Rhoades
Senior Lecturer
Department of Systems
Engineering
831-277-9153
mmrhoade@nps.edu

Marcello Romano
Associate Professor
Department of Mechanical and
Aerospace Engineering
831-656-2885
mromano@nps.edu

Alan A. Ross
Professor of Practice
Department of Electrical and
Computer Engineering
831-656-3769
aross@nps.edu

I. Michael Ross
Professor
Department of Mechanical and
Aerospace Engineering
831-656-2074
imross@nps.edu

Daniel Sakoda
Research Associate
831-656-3198
dsakoda@nps.edu

Alan D. Scott
Senior Lecturer
Department of Mechanical and
Aerospace Engineering
831-656-2453
adscott@nps.edu

Stephen Tackett
LCDR, USN, Military Faculty
Lecturer and Program Officer
831-656-2944
shackett@nps.edu

David Trask
MASINT Chair Professor
Department of Physics
831-656-2219
dmtrask@nps.edu

Donald van Zelm Wadsworth
Senior Lecturer
Department of Electrical and
Computer Engineering
831-656-3456
dwadsworth@nps.edu

Donald L. Walters
Professor
Department of Physics
831-656-2267
walters@nps.edu

Todd Weatherford
Associate Professor
Department of Electrical and
Computer Engineering
831-656-3044
trweathe@nps.edu

William, J. Welch
Lecturer, Department of
Information Sciences
831-656-3212
wwelch@nps.edu

SPACE SYSTEMS ACADEMIC GROUP

COMPUTER ALGORITHMS AND ARCHITECTURES FOR SPACE APPLICATIONS (PROJECT GUSTY ORIOLE)

Herschel H. Loomis, Jr., Professor
Space Systems Academic Group

Sponsor: Secretary of the Air Force/FMBIB-AFOY

OBJECTIVE: To develop specialized algorithms and architectures for space applications.

THE CONFIGURABLE FAULT-TOLERANT ARCHITECTURE FOR RELIABLE SPACE- BASED COMPUTING (CFTP)

Herschel H. Loomis, Jr., Professor
Space Systems Academic Group

Sponsor: Secretary of the Air Force/FMBMB-AFOY

OBJECTIVE: To demonstrate the value of the remote configurability of the field-programmable gate array (FPGA) to space computing. To develop an SEU-tolerant space-based computer using commercial, off-the-shelf FPGAs to demonstrate the feasibility of using triple modular redundancy (TMR) to correct errors without resort to system reset. To build and fly a configurable, fault-tolerant, mission computer on NPSSAT, MidSTAR, and a satellite in a high-radiation orbit.

FAULT-TOLERANT TECHNIQUES AS APPLIED TO RECONFIGURABLE ARCHITECTURES (CFTP-SPONSOR 3)

Herschel H. Loomis, Jr., Professor
Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: To demonstrate the value of the remote re-configurability of GAS to space computing. To develop and test SEU-tolerant space-based computer architectures using commercial, off-the-shelf field-programmable gate arrays (FPGAs) to demonstrate the feasibility of using various types of redundancy and coding techniques to correct data and configuration errors in important satellite subsystems, such as software defined radios. To build and fly a configurable, fault-tolerant, mission computer on NPSAT and on a satellite in a high-radiation orbit. To continue to operate the existing CFTP on MidSTAR-1. To test the CFTP concepts in a ground-based radiation facility.

OPTIMIZATION AND DESIGN OF HIGH-EFFICIENCY, SPACE-BASED, MULTI-JUNCTION SOLAR CELLS USING SILVACO VIRTUAL WAFER FABRICATION SOFTWARE

Sherif N. Michael, Professor
Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: To design and optimize state-of-the-art, space-based solar cells. A new method for developing a realistic model of any type of solar cell using the Silvaco/ATLAS Virtual Wafer Fabrication software was developed at the Naval Postgraduate School (NPS). Taking into account the high cost of research and experimentation involved with the development of advanced cells, this novel methodology was developed. The introduction of this modeling technique to the photovoltaic community will prove to be of great importance in aiding in the design and development of advanced solar cells. A multi-junction InGaP/GaAs/Ge solar cell was successfully modeled and fully simulated. The simulation results were comparable to published experimental data of similar cells. Further research for the development of a more accurate model that can be used for the design and optimization of advanced multi-junction cells is proposed. Another major goal of this research is to bridge the gap between current, state-of-the-art, manufactured cells at 30% efficiency and the theoretical limit of more than 40%. Further research in optimizing solar cells output power for high temperature and/or radiation environment realistic space operations is proposed.

SPACE SYSTEMS ACADEMIC GROUP

CUBESAT DEPLOYABLE MECHANISMS AND ATTITUDE CONTROL SYSTEM PROTOTYPES

James H. Newman, NASA Chair Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: To develop deployable mechanisms for use on CubeSats, specifically, deployable solar panels and a deployable boom; and to develop a simple, low-cost, attitude-control subsystem. The intent is to do this development in a phased approach. This phase one proposal sets reasonable goals that complement each other and the other CubeSat work being done at the Naval Postgraduate School (NPS). Phase two proposals will incorporate the results of this work into flight units and propose areas for follow-on research. Specifically, the development of solar-array gimbel mechanisms to permit solar-array sun tracking is of interest in the future. This work is also consistent with the NPS educational mission.

DESIGN AND QUALIFICATION TESTING OF THE NAVAL POSTGRADUATE SCHOOL CUBESAT LAUNCHER

James H. Newman, Professor
Space Systems Academic Group
Sponsor: National Science Foundation, National Reconnaissance Office,
California Space Education and Workforce Institute

OBJECTIVE: To investigate a method to substantially increase the number of CubeSat launch opportunities for U.S. government, industry, and academic CubeSat developers on U.S. launches. Although originally developed as a satellite standard in the U.S., most CubeSats are launched overseas due to the difficulty of getting secondary payloads onto domestic launches. This project takes the development of a CubeSat Launcher from the model stage through the design, construction, and test of a flight-qualified unit.

SUMMARY: This project continued the phase one work sponsored by the California Space Education and Workforce Institute to produce a one-half-scale model of a CubeSat Launcher, or NPSCuL. The NPSCuL project continued with Naval Postgraduate School (NPS) students developing the prototype into a flight unit. A student Program Manager was in charge of the overall project, including budget and schedule, and the student team divided up responsibilities for the deliverables. The sponsor had identified a flight opportunity in late 2010 on a domestic launch for NPSCuL, and the prospect of a launch added realism and urgency to the project. The project made considerable progress in CY09 in preparation for an August 2010 launch on NRO L-41. In December 2009, it was demanifested from that launch when the primary complement of CubeSats backed out due to schedule issues. Work continues in anticipation of future flight opportunities.

PRESENTATIONS:

DeJesus, A.C., Hicks, C.M., Crook, M.R., Harris, A.D., and Newman, J.H., "NPS CubeSat Launcher (NPSCuL) Program Update," CubeSat Developers Workshop, 27 April 2009.

Hicks, C.M., Sakoda, D., Panholzer, R., and Newman, J.H., "NPS CubeSat Launcher Lite," 2009 NRO Government Forum on CubeSats, February 2009 (invited).

Hicks, C.M., DeJesus, A.C., Harris, A.D., Crook, M.R., Rossberg, F., Sakoda, D., et al., "Coach Class to Orbit: The NPS CubeSat Launcher," Twenty-Third AIAA/USU Conference on Small Satellites, Logan, Utah, SSC09-X-9, 2009.

THESES DIRECTED:

Crook, M., "NPS CubeSat Launcher Design, Process, and Requirements," Master's Thesis, Naval Postgraduate School, June 2009.

SPACE SYSTEMS ACADEMIC GROUP

DeJesus, A., "Integration and Environmental Qualification Testing of Spacecraft Structures in Support of the Naval Postgraduate School CubeSat Launcher Program," Master's Thesis, Naval Postgraduate School, June 2009.

Harris, A., "NPS CubeSat Launcher-Lite Sequencer," Master's Thesis, Naval Postgraduate School, June 2009.

Hicks, C., "NPS CubeSat Launcher Program Management," Master's Thesis, Naval Postgraduate School, September 2009.

OTHER:

This project was successfully presented to the Department of the Navy and the Department of Defense Space Experiments Review Board for consideration for a launch opportunity. The NPSCuL project has been ranked by the DoD Review Board for an eventual launch opportunity.

KEYWORDS: CubeSat, Launcher, Pico-Satellite, Domestic Launch

THE NPSCUL-LITE FLIGHT UNIT FOR ADAMSAT

James H. Newman, NASA Chair Professor
Space Systems Academic Group
Sponsor: National Science Foundation

OBJECTIVE: To produce a flight unit CubeSat launcher (NPSCuL-Lite) and associated activities as part of the AS&T development and maturation satellite (AdamSat). The first flight of AdamSat is currently scheduled for no earlier than August 2010 as part of the NROL-41 launch. NPSCuL-Lite will be aft bulkhead carrier and ESPA-compatible and is required in support of the launch of Firefly.

PHASE II: FLIGHT-BUILD OF A NANOSATELLITE ADVANCED-SOLAR-CELL TESTER

James H. Newman, NASA Chair Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: To build a flight-unit solar-cell tester as a follow-on to the on-going phase one project funded by National Reconnaissance Office (NRO) AS&T to design and prototype a solar-cell tester using a CubeSat platform. This on-going research is currently the thesis project for a Naval Postgraduate School (NPS) graduate student. This student is the "program manager" for the phase one effort, whereby he is responsible for the project's budget, schedule, and deliverables. Two first-year students also have signed up for directed studies to assist on the phase one project, "working" for the student program manager. The CubeSat-class satellite is beginning to provide NPS researchers and students with exciting, relatively short turnaround research projects in rapid-prototyping and low-cost flight testing of advanced materials and systems and other research payloads and for satellite engineering and operations. This proposal addresses the NRO key functional capability number six, Innovative Capabilities.

PHASE III: FLIGHT-BUILD OF A NANOSATELLITE ADVANCED-SOLAR-CELL TESTER

James H. Newman, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office, Advance Systems and Technology-Outreach Program

OBJECTIVE: To investigate the use of very small satellites to accomplish focused research of national interest. To support this objective, this project will produce the Naval Postgraduate School's (NPS) first satellite using the CubeSat form factor, thereby gaining experience in all phases of CubeSat systems integration, payload development, and flight operations. The use of the CubeSat form factor is expected to

SPACE SYSTEMS ACADEMIC GROUP

enhance our ability to perform certain research of national interest that is also accessible and interesting to the NPS student body. The first CubeSat characterizes the performance of various solar cells in the space environment. The results are of general interest and demonstrate the capability of the CubeSat as a technology demonstration satellite, as well as a potential platform for more sophisticated experiments, while still actively involving NPS students.

SUMMARY: This project continued work done under phases one and two with the goal to produce a deliverable NPS Solar Cell Array Tester (NPS-SCAT). A launch capability may be available in early 2011. NPS' first CubeSat takes one experiment, the Solar Cell IV Curve Tester, from NPSAT1 and repackages it to fit in the CubeSat form factor. In CY09, a team of NPS students effectively finished the engineering unit and began testing the SCAT systems and payload.

PRESENTATION:

Ortiona, et al., "The Naval Postgraduate School SCAT++ CubeSat Program," Twenty-Third AIAA/USU Conference on Small Satellites, Logan, Utah, SSC09-XII-4, 2009.

THESES DIRECTED:

Dorn, L.T., "NPS-SCAT: Electrical Power System," Master's Thesis, Naval Postgraduate School, September 2009.

Malone, C.S., "NPS Solar Cell Array Tester: A Program Management Analysis," Master's Thesis, Naval Postgraduate School, September 2009.

Schroer, M., "NPS-SCAT: A CubeSat Communications System Design, Test, and Integration," Master's Thesis, Naval Postgraduate School, June 2009.

OTHER:

This project was successfully presented to the Department of the Navy and the Department of Defense Space Experiments Review Board and ranked for an eventual launch opportunity.

KEYWORDS: CubeSat, Solar Cell, Pico-Satellite, NPS-SCAT

THE STUDENT RIDESHARE PAYLOAD MODEL

James H. Newman, NASA Chair Professor

Space Systems Academic Group

Sponsor: California Space Education Workforce Institute

OBJECTIVE: The Naval Postgraduate School (NPS) has robust space-systems engineering and operations research and education programs. The operations education/research focuses on the design, development, and acquisition management of space communications, navigation, surveillance, electronic warfare, and environmental sensing systems. The engineering education/research encompasses the operation, tasking, and employment of space surveillance, communications, navigation and atmospheric, oceanographic, environmental sensing systems, as well as payload design and integration – specifically for the exploitation of space and information projects.

The California Space Education and Workforce Institute (CSEWI) is a non-profit organization whose mission includes space-related education and concentrated programs to advance space science, engineering, and technology.

NPS and CSEWI will collaborate to produce and qualify a student payload launcher and update requirements and process information to improve student access to launch opportunities.

SPACE SYSTEMS ACADEMIC GROUP

THE USE OF VERY SMALL SATELLITES IN RESEARCH AND EDUCATION AT THE NAVAL POSTGRADUATE SCHOOL

James H. Newman, NASA Chair Professor

Space Systems Academic Group

Sponsor: Naval Postgraduate School

OBJECTIVE: To pursue the use of very small satellites to accomplish focused research objectives of national interest. This research will procure and integrate core systems for a very small satellite in response to a flight opportunity on the space shuttle in 2010. It will also develop a magnetic environment test laboratory. As part of the effort to provide useful systems for CubeSats, it is desired to improve our ability to provide more than rudimentary attitude control of CubeSats, and the use of the earth's magnetic field to provide attitude is important.

SUMMARY: The Research Initiation Program (RIP) proposal focused on developing CubeSat systems and a magnetic test facility for attitude control. Work is progressing well and also includes progress on the CubeSat core systems and the ground station for communicating with CubeSats when they are in space. Two summer STEP employees validated existing structural designs by independently calculating the magnetic fields produced by the Helmholtz coils. The coils have been wrapped and the magnetic fields now need to be measured and calibrated. The work will continue in CY10 with RIP support.

A provisional patent was filed based on collaborative work with Professor Romano on his TINYScope project. A very small release mechanism for use with small satellites was produced using the properties of shape memory alloys in an unconventional manner.

In addition, travel to CubeSat and Small Satellite Conferences was supported. Other travel included trips to the United Launch Alliance for the NPSCuL (NPS CubeSat Launcher) and NPS-SCAT (NPS Solar Cell Array Tester) projects. This project also provided an opportunity for seeking collaborative opportunities with other civilian and government universities, such as CSUMB, USAFA, University of Michigan, and AFIT. The principal investigators are pleased to be collaborating with CSUMB on a senior capstone project and hope this will be the catalyst for future capstone projects with other CSUMB students.

PATENT APPLICATION:

Crane, W., Oppenheimer, P., Romano, M., and Newman, J., "Micro-Coupling Active Release Mechanism," provisional patent filed August 2009.

KEYWORDS: CubeSat, Magnetic Test Facility, Helmholtz Coils, Attitude Control, Collaborative Ventures

THE NAVAL SPACE SYSTEMS ACADEMIC CHAIR

Rudolf Panholzer, Professor and Chair

Space Systems Academic Group

Sponsor: Naval Network Warfare Command

OBJECTIVE: The incumbent of the Naval Space Systems Academic Chair will engage in instruction and research and act as a consultant in the area of specialization to students and faculty of the Naval Postgraduate School (NPS).

SUMMARY: The instructional, research, and advisory program carried out by the Naval Space Systems Academic Chair was comprised of various activities, including stimulating and participating in appropriate faculty research and coordinating and supervising student research. The chair supported and guided ongoing curriculum and laboratory development at NPS; presented/coordinated seminars as mutually agreed upon with the SSAG Chairman in areas of common interest; taught courses as appropriate; and acted as a conduit between the Naval Network Warfare Command and NPS on the latest developments in space systems and their impact on future Naval operations and resources.

KEYWORDS: SATCOMM, Space Control, Space Systems Architecting, TENCAP

SPACE SYSTEMS ACADEMIC GROUP

THE SPACE SYSTEMS ENGINEERING EXPERIENCE TOUR AND SPACE SYSTEMS ENGINEERING SUPPORT

Rudolf Panholzer, Professor and Chair

Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: To fund Space Systems Academic Group Space Systems Engineering Space Cadre support and Space Systems Engineering Experience Tours.

THE SPACE SYSTEMS ENGINEERING EXPERIENCE TOUR AND SPACE SYSTEMS ENGINEERING SUPPORT

Rudolf Panholzer, Professor and Chair

Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: To fund Space Systems Academic Group Space Systems Operations student thesis research-related travel and Experience Tour travel.

THE SPACE SYSTEMS ENGINEERING EXPERIENCE TOUR AND SPACE SYSTEMS ENGINEERING SUPPORT

Rudolf Panholzer, Professor and Chair

Space Systems Academic Group

Sponsor: National Reconnaissance Office

OBJECTIVE: To fund the Space Systems Academic Group Space Systems, engineering support, engineering student thesis research, related travel, and Experience Tour travel.

SUMMARY: This research is one of the main sources of funding for the Space Systems Academic Group. The bulk of the money supported the engineer's labor used to assist graduate students as they worked on research related to their thesis projects. The students participated in hands-on research involving on-going projects, giving them invaluable experience in design, development, installation, system integration, and maintenance of spacecraft and payloads.

Another significant segment of the funds was used to financially support the travel needed to work on their thesis and for Experience Tour travel. The Experience Tour encompassed two weeks of off-site visiting to the Department of Defense, NASA, other government sites, and commercial installations as a group to gain exposure to different facilities and their functions.

KEYWORDS: Space Systems Instructional, Research and Advisory

SPACE SYSTEMS OPERATIONS THESIS RESEARCH/EXPERIENCE TOUR

Rudolf Panholzer, Professor and Chair

Space Systems Academic Group

Sponsor: Naval Network Warfare Command

OBJECTIVE: To fund the Space Systems Academic Group (SSAG) Space Systems Operations student thesis research-related travel and Experience Tour travel.

SUMMARY: This research allowed students to conduct on-site research and learning in support of thesis development. It also provided students an opportunity to participate in Experience Tour travel. The Experience Tour encompassed two weeks of off-site visiting to the Department of Defense, NASA, other government sites, and commercial installations as a group to gain exposure to different facilities and their functions.

SPACE SYSTEMS ACADEMIC GROUP

KEYWORDS: Space Systems Operations, Instructional, Research and Advisory

THE STUDENT RIDESHARE PAYLOAD MODEL

Rudolf Panholzer, Professor and Chair

Space Systems Academic Group

Sponsor: California Space Education Workforce Institute

OBJECTIVE: The Naval Postgraduate School has robust space systems engineering and operations research and education programs. The operations education/research focuses on the design, development, and acquisition management of space communications, navigation, surveillance, electronic warfare, and environmental sensing systems.

A CASE STUDY OF A NATIONAL SECURITY SPACE PROGRAM

CAPT Alan Scott, USN, Military Instructor

Space Systems Academic Group

Sponsor: Secretary of the Air Force/FMBIB-AFOY

OBJECTIVE: A case study of a national security space program is proposed. Case studies facilitate learning by emphasizing the long-term consequences of systems engineering and programmatic decisions on cost, schedule, and operational effectiveness of major programs. The proposed effort will support the thesis research of several students, and the resultant report will be used to supplement learning in the Naval Postgraduate School Space Systems curricula and the National Security Space (NSS) Acquisition and Systems Engineering education programs.

THE NAVAL SPACE SYSTEMS ENGINEERING AND ACQUISITION CHAIR

CAPT Alan Scott, USN, Military Instructor

Space Systems Academic Group

Sponsor: Program Executive Office for Space Systems

OBJECTIVE: To promote and guide a focused instructional and research program in Space Systems Engineering and Acquisition (SSEA) at the Naval Postgraduate School, which will support the design, development, integration, test, launch and on-orbit sustainment of Naval space systems. The roles and responsibilities governing the Naval SSEA chair will be defined in a memorandum of agreement pending signature by the President, Naval Postgraduate School, and the Program Executive Officer for Space Systems.

SPACE SYSTEMS ACADEMIC GROUP

**2009
Faculty Publications
and Presentations**

PRESENTATIONS

DeJesus, A.C., Hicks, C.M., Crook, M.R., Harris, A.D., and Newman, J.H., “NPS CubeSat Launcher (NPSCuL) Program Update,” CubeSat Developers Workshop, 27 April 2009.

Hicks, C.M., Sakoda, D., Panholzer, R., and Newman, J.H., “NPS CubeSat Launcher Lite,” 2009 NRO Government Forum on CubeSats, February 2009 (invited).

Hicks, C.M., DeJesus, A.C., Harris, A.D., Crook, M.R., Rossberg, F., Sakoda, D., et al., “Coach Class to Orbit: The NPS CubeSat Launcher,” Twenty-Third AIAA/USU Conference on Small Satellites, Logan, Utah, SSC09-X-9, 2009.

Horning, J., “NPSAT1 Small Satellite, Experiment Number: NPS-0001,” Department of Defense Space Experiments Review Board, November 2009.

Horning, J., “NPSAT1 Small Satellite, Experiment Number: NPS-0001,” Navy Space Experiments Review Board, July 2009.

Ortiona, et al., “The Naval Postgraduate School SCAT++ CubeSat Program,” Twenty-Third AIAA/USU Conference on Small Satellites, Logan, Utah, SSC09-XII-4, 2009.

**GRADUATE SCHOOL
OF BUSINESS AND
PUBLIC POLICY**

**WILLIAM GATES
DEAN**

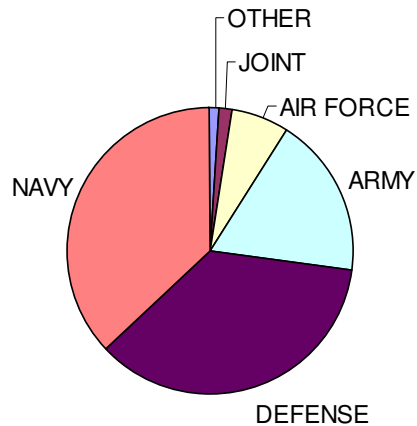
GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

OVERVIEW:

The Graduate School of Business and Public Policy offers a unique, residential, defense-focused MBA program, plus Master's degrees in five other Department of Defense-relevant areas. Faculty research is an important component of the school and strives to support military decision making, problem solving, and policy setting; improve administrative processes and organizational effectiveness; contribute knowledge to academic disciplines; and advance the mission of graduate education. The research program is integrated to the greatest possible extent with the educational process. Students are encouraged to participate in faculty projects, and faculty research results are typically incorporated in classroom instruction. Topics and issues can be grouped into five broad functional areas: acquisition and contracting; budgeting and financial management; logistics and transportation; manpower-systems analysis; and policy formulation, analysis, and management.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Graduate School of Business and Public Policy is provided below:



Size of Program: \$7.5M

GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

William Gates
Associate Professor and Dean
831-656-2754
bgates@nps.edu

James E. Suchan
Professor and Associate Dean
for Distance Learning
831-656-2905
jsuchan@nps.edu

Stephen L. Mehay
Professor and Associate Dean
for Research
831-656-2643
smehay@nps.edu

Aruna Apte
Assistant Professor
831-656-7583
auapte@nps.edu

Peter Coughlan
Associate Professor
831-656-2659
picoughl@nps.edu

Raymond E. Franck
Senior Lecturer
831-656-3614
refranck@nps.edu

Uday Apte
Professor
831-656-3598
umapte@nps.edu

Alice M. Crawford
Senior Lecturer
831-656-2481
acrawford@nps.edu

Deborah E. Gibbons
Associate Professor
831-656-1842
degibbon@nps.edu

Jeremy Arkes
Associate Professor
831-656-2646
jaarkes@nps.edu

Nicholas Dew
Associate Professor
831-656-3622
ndew@nps.edu

James B. Greene
RADM, USN (Ret.)
Visiting Senior Lecturer and
Acquisition Chair
831-656-2092
jbgreene@nps.edu

Frank J. Barrett
Professor
831-656-2328
FBarrett@nps.edu

John T. Dillard
Senior Lecturer
831-656-2650
jtdillar@nps.edu

William D. Hatch, II
Lecturer
831-656-2463
wdhatch@nps.edu

Michael W. Boudreau
Senior Lecturer
831-656-3420
mboudreau@nps.edu

Kenneth H. Doerr
Associate Professor
831-656-3625
kndoerr@nps.edu

Timothy G. Hawkins
Maj, USAF, Military Faculty
Assistant Professor
831-656-7647
tghawkin@nps.edu

Douglas E. Brinkley
Senior Lecturer
831-656-2771
brinkley@nps.edu

Richard B. Doyle
Associate Professor
831-656-3302
rdoyle@nps.edu

Susan K. Heath
Assistant Professor
831-656-2093
skheath@nps.edu

Douglas A. Brook
Professor and Director,
Center for Defense
Management Research
831-656-2161
dabrook@nps.edu

Mark J. Eitelberg
Professor of Public Policy
831-656-3160
meitelberg@nps.edu

David R. Henderson
Associate Professor
831-656-2524
drhender@nps.edu

Philip J. Candrea
Senior Lecturer of Budgeting
and Senior Associate, Center
for Defense Management
Research
831-656-2884
picandrea@nps.edu

Kenneth J. Euske
Professor
831-656-2860
kjeuske@nps.edu

Geraldo Ferrer
Associate Professor
831-656-3290
gferrer@nps.edu

Nayantara Hensel
Assistant Professor
831-656-3542
ndhensel@nps.edu

GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

Susan P. Hocevar
Associate Professor
831-656-2249
shocevar@nps.edu

Bryan J. Hudgens
Lt Col, USAF, Military
Faculty, Lecturer, and Air
Force Acquisition
Representative
831-656-2039
bjhudgen@nps.edu

Lawrence R. Jones
Professor, Wagner Chair
831-656-2482
lrjones@nps.edu

Keebom Kang
Associate Professor
831-656-3106
kkang@nps.edu

Cynthia King
Assistant Professor
831-656-3228
clking@nps.edu

Alan Laverson
Assistant Professor
831-656-3930
ajlavers@nps.edu

Ira A. Lewis
Associate Professor
831-656-2464
ialewis@nps.edu

David F. Matthews
Senior Lecturer
831-656-2360
dmatthews@nps.edu

Douglas Moses
Vice Provost for Academic
Affairs
831-656-3218
dmoses@nps.edu

John E. Muttty
Senior Lecturer
831-656-2205
jmuttty@nps.edu

Noah Myung
Assistant Professor
831-656-2811
noah.myung@nps.edu

Brad Naegle
Senior Lecturer
831-656-3620
bnaegle@nps.edu

Rich Nalwasky
CDR, USN, Military Faculty
831-656-3986
rnalwask@nps.edu

Walter E. Owen
Senior Lecturer
831-656-2048
wowen@nps.edu

Elda Pema
Assistant Professor
831-656-3631
epema@nps.edu

Diana Petross
Lecturer
831-656-7646
dfpetros@nps.edu

Lisa F. Potvin
Lecturer and Program
Manager
719-357-0679
lfpotvin@nps.edu

Edward H. Powley
Assistant Professor of
Management
831-656-2768
ehpowley@nps.edu

Juanita M. Rendon
Lecturer
831-656-2444
jmrendon@nps.edu

Rene G. Rendon
Associate Professor
831-656-3464
rgrendon@nps.edu

Benjamin Roberts
Research Associate Professor
831-656-2792
broberts@nps.edu

Susan M. Sanchez
Professor
831-656-2780
ssanchez@nps.edu

Joseph G. San Miguel
Professor
831-656-2187
jsanmiguel@nps.edu

Yu-Chu Shen
Associate Professor
831-656-2951
yshen@nps.edu

Cary A. Simon
Lecturer
831-656-2439
csimon@nps.edu

Keith F. Snider
Associate Professor
831-656-3621
ksnider@nps.edu

Donald E. Summers
Senior Lecturer
831-656-3632
desummer@nps.edu

Gail Fann Thomas
Associate Professor
831-656-2756
gthomas@nps.edu

George W. Thomas
Professor
831-656-2741
gwthomas@nps.edu

Brett Wagner
CDR, USN, Military Faculty
831-656-3419
bawagner@nps.edu

Chong Wang
Assistant Professor
831-656-2665
cwang@nps.edu

Elliott Cory Yoder
Senior Lecturer and
Academic Associate
831-656-3619
ecyoder@nps.edu

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Keenan D. Yoho
Assistant Professor
831-656-2029
kdyoho@nps.edu

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ANALYZING THE PREDICTORS AND CONSEQUENCES OF RISKY TEENAGE BEHAVIOR AND LIFE CHOICES

Jeremy Arkes, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Naval Postgraduate School

OBJECTIVE: To continue existing work and begin new examinations on the causes and consequences of problem behaviors and outcomes for youth. In particular, this research will focus on substance abuse, teenage fertility, obesity, and problem behavior. This work will be informative to the Department of Defense, as it could help predict trends in the characteristics of the potential pool from which the future force will be drawn. The principal investigator will translate the models examining youth decisions to improve enlistment models.

THE DEPARTMENT OF THE NAVY CHIEF MANAGEMENT OFFICER: A WORKSHOP TO EXPLORE FOUNDATIONS FOR THE CMO/DCMO IN THE DEPARTMENT OF THE NAVY

Douglas A. Brook, Professor
Graduate School of Business and Public Policy
Sponsor: Office of the Deputy Under Secretary of the Navy

OBJECTIVE: Based on preliminary discussions with the Under Secretary of the Navy and the Deputy Under Secretary of the Navy for Business Enterprise Operations and Transformation, this proposal is submitted to assist Navy leadership in further developing the concept and operations of the Office of CMO for the Department of the Navy. The Center for Defense Management Research (CDMR) has previously been engaged in applied research for the Department of Defense Business Transformation Agency, and some of its researchers have previous experience working in Department of the Navy business transformation.

IMPLEMENTATION OF NSPS AND DEPARTMENT OF HOMELAND SECURITY PERSONNEL SYSTEMS

Douglas A. Brook, Professor
Graduate School of Business and Public Policy
Sponsor: Program Executive Office for the National Security Personnel System

OBJECTIVE: To write a technical report on the remaining story of personnel policy implementation. This report will provide the basis for additional journal publications and eventually a book on personnel management reform.

A STUDY OF BUDGET FORMULATION AND EXECUTION IN THE DEFENSE MANPOWER DATA CENTER

Douglas A. Brook, Professor
Graduate School of Business and Public Policy
Sponsor: Defense Manpower Data Center

OBJECTIVE: The Center for Defense Management Research (CDMR) recommends a study that examines the budget formulation and execution processes at the Defense Manpower Data Center (DMDC). The purposes of this study are first, to examine the policies, practices, and cultural influences in DMDC budget formulation and execution; second, to develop models of budget formulation and execution and a change-management strategy that could serve the DMDC's need for budgetary efficiency, stewardship, accountability, and strategic alignment; and third, to develop recommendations and change-management strategies.

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BARRIERS TO IMPLEMENTING LED LIGHTING INNOVATIONS IN THE NAVY

Nicholas Dew, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Office of Naval Research

OBJECTIVE: To assess the barriers to implementation of LED lighting innovations in the Navy surface and undersea fleets.

RESOURCING SUBMARINE OPERATIONS IN THE PACIFIC, EXTRACTING DATA ON SUBMARINE OPERATIONS FROM PBIS

Richard B. Doyle, Associate Professor
Graduate School of Business and Public Policy
Sponsor: U.S. Pacific Fleet

OBJECTIVE: To identify funding provided by the FY09 Defense Appropriations Bill in support of operations of submarines in the Atlantic and the Pacific, separating and comparing funds for submarines in each of the two fleets and breaking out the funds in detail. To provide a briefing on the total federal budget, and the FY09 budget for the Department of Defense and shipbuilding in general, including the budget impact of the initiatives taken by the government to mitigate the impact of the economic crisis.

SUPPORT TO COMMANDER, NAVAL SURFACE FORCES

Kenneth J. Euske, Professor
Graduate School of Business and Public Policy
Sponsor: Naval Surface Forces

OBJECTIVE: To provide support to Commander, Naval Surface Forces to address issues regarding costing, process analysis, internal control, and training.

SUPPORT TO COMMANDING OFFICER, FLEET RESOURCES CENTER

Kenneth J. Euske, Professor
Graduate School of Business and Public Policy
Sponsor: Fleet Readiness Center Southwest

OBJECTIVE: To provide support to the Commanding Officer, Fleet Resources Center Southwest to address costing, marketing, and process issues.

THE LOGISTICS AUTOMATION MANAGER

Geraldo Ferrer, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Naval Supply Systems Command

OBJECTIVE: COMFISCS WNY desires to have faculty and students from the Naval Postgraduate School (NPS) engage in supply-chain-management research involving topics that are of importance to the Program Executive Office, the Department of the Navy, and the Department of Defense (DoD). In furthering this objective, NPS will conduct research about the use of UID for tracking valuable assets in the Naval supply chain, and for the development of educational materials to disseminate the respective knowledge among NPS students and members of the DoD community. NPS faculty and students will undertake specific research projects identified by COMFISCS WNY within the scope of the Graduate School of Business and Public Policy's expertise in supply chain management. If specific projects are not delineated, the principal investigator will apply discretion in determining the use of funds towards relevant research and studies in supply chain management. The deliverables will be in the form of one or more student theses. This study is

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being executed as part of the partnership between the COMFISCS ULD Project Manager and the Graduate School of Business and Public Policy.

THE UID TRACKING – ACQUISITION RESEARCH PROGRAM

Geraldo Ferrer, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Naval Supply Systems Command

OBJECTIVE: The Acquisition Chair is responsible for, among other things, managing acquisition research for COMFISCS WNY and the Naval Postgraduate School, including: coordinating research opportunities for NPS faculty, stimulating research projects by selected graduate students, traveling as necessary to support research objectives, and providing seminars and symposiums. Graduate School of Business and Public Policy faculty and students will undertake specific research projects identified by COMFISCS WNY, however, if specific projects are not delineated, the Acquisition Chair will apply discretion in determining the appropriate scope and depth of research work to be performed in consultation with COMFISCS.

CAPACITY MODELING OF THE FLEET READINESS CENTER SOUTHWEST, PHASE 1

Susan K. Heath, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Fleet Readiness Center Southwest

OBJECTIVE: To construct and test a capacity simulation model of the Fleet Readiness Center Southwest (FRCSW). All major aircraft platforms; major types of maintenance, repair, and overhaul (MRO); and major phases of MRO will be modeled. This includes the consolidation of existing process and flow data, which will be provided by the FRCSW. The data will then be used to construct a discrete-event simulation model. The model will be designed to allow for experimentation to test a variety of questions.

AN ANALYSIS OF FLIGHT-HOUR PROGRAM MANAGEMENT, BUDGET EXECUTION, COST-AVOIDANCE, AND FINANCIAL MANAGEMENT INITIATIVES IN CNAP

Lawrence R. Jones, Professor
Graduate School of Business and Public Policy
Sponsor: U.S. Pacific Fleet

OBJECTIVE: To provide analytical assistance to the Office of Comptroller, CNAP, in the comptroller function and in analysis of budget execution and other initiatives for improving command management and management control, achieving cost-reduction and avoidance in the Flight Hour Program (FHP), and accommodating budget reduction in the period FY09, FY10, and beyond. In addition, the project includes an analysis of improvements in management systems and systems support to provide better data to enable management of the command in conformance with sound business-management principles and practices.

AN ANALYSIS OF FLIGHT-HOUR PROGRAM MANAGEMENT, BUDGET EXECUTION, COST-AVOIDANCE, AND FINANCIAL MANAGEMENT INITIATIVES IN CNAP

Lawrence R. Jones, Professor
Graduate School of Business and Public Policy
Sponsor: Naval Air Pacific Command

OBJECTIVE: To provide analytical assistance to the Office of the Comptroller, CNAP, in the comptroller function and in analysis of budget execution and other initiatives for improving command management and management control, achieving cost-reduction and avoidance in the Flight Hour Program (FHP), and accommodating budget reduction in the period FY08, FY09, and beyond. In addition, the project includes

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an analysis of improvements in management systems and systems support to provide better data to enable management of the command in conformance with sound business-management principles and practices.

THE BUSINESS TRANSFORMATION AGENCY: MANAGING THE TRANSITION 2009/2010

Cindy King, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Business Transformation Agency

OBJECTIVE: The Defense Business Transformation Agency (BTA) will, like other federal agencies, face new challenges in light of the changes introduced by a new presidential administration. Following on the CDMR's research into the BTA's value proposition, perceptions within the Office of the Secretary of Defense, and preliminary perspectives on business transformation by President Elect Obama, the principal investigators will provide additional research to assist the BTA in applying its strengths and opportunities to achieve its goals within the Department of Defense. CDMR will provide research assistance to the ETA in various areas, including strategic communication, performance management, interagency collaboration, and organizational behavior assessment. Drawing on a combination of both quantitative and qualitative research approaches and an understanding of the ETA and its mission within the Department of Defense, the principal investigators will work with ETA leadership to identify key projects of interest.

DCAA OFFSITE FACILITATION: CREATING THE ORGANIZATIONAL/CULTURAL ISSUE AGENDA

Cindy King, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Defense Contract Audit Agency

OBJECTIVE: To develop the workshop to meet DCAA's specific needs; prepare all supporting materials; send two research professors to the meeting location (Atlanta, Georgia); conduct the workshop and facilitate the process; and create, in conjunction with the executive team, the DCAA Issue Agenda. The primary researchers for this project will be Dr. Cary Simon and Dr. Cynthia King.

EXPLORING COMMUNICATION STRATEGIES: AN EXAMINATION OF A U.S. FEDERAL AGENCY

Cindy King, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Defense Contract Audit Agency

OBJECTIVE: The Defense Contract Audit Agency (DCAA) seeks to assess their agency to identify key issues for improving and transforming their organizational culture, particularly for ensuring a shared understanding and commitment to strategic objectives. There is much literature that links the quality of leadership to the quality of leader communication (e.g., Mayfield, Mayfield, and Kopf, 1998; Mayfield and Mayfield, 2002; Michael, Harris, Giles, and Fields, 2005; Riggio, Salinas, Riggio, and Cole, 2003; Young and Post, 1993). Additionally, previous research has shown that leader communications were critical to change initiatives in the U.S. auto industry and in U.S. Naval aviation (King, 2006). However, very little research has been done that focuses on the relationship between leader communicative intent and employee/manager response in U.S. federal agencies. This study will investigate a policy-change memo issued by the Director of DCAA and its reception by employees throughout all layers of the organization. This study seeks not only issues of comprehension of policy content, but how employees make sense of the communication.

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N4 TASK FORCE ENERGY – STRATEGIC COMMUNICATION PLANNING AND ASSESSMENT

Cindy King, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Chief of Naval Operations

SUMMARY: Based on preliminary discussions with N4, the Center for Defense Management Reform (CDMR) recommends a study that examines communication as a key strategic factor for standing up Task Force Energy (TFE). The task force is in the early stages of formation and is tasked with designing a strategic plan for moving the Navy's energy plans forward. The Navy's energy strategy will address both shore and tactical consumption and requires a high degree of strategic communication analysis and assessment. This plan will face challenges since supporting actions will need to be executed across multiple command structures with very little central tasking authority. This will necessitate early stakeholder buy-in and an effective communication plan. As TFE moves through its strategic planning process, it will also benefit from a solid knowledge of best practices for building stakeholder buy-in. This research will assist the TFE in understanding specific stakeholder goals, motivations, processes, and roles that will be essential in developing an effective communication plan. The research methods employed will include both qualitative and quantitative data gathering. Qualitative interviews will be transcribed and analyzed; quantitative survey data will be analyzed for statistic significance.

INNOVATION RESEARCH
CAPT Terri Rea, USN, Military Faculty
Graduate School of Business and Public Policy
Sponsor: Office of Naval Research

OBJECTIVE: To train a critical mass of Naval (and other) leaders in order to effect a state change in the effectiveness and strategic value of their innovation efforts, and to create an innovation initiative located at the Naval Postgraduate School (NPS) that will aggregate resources and best practices so that it becomes a hub for innovation "know-how" and "know-what." The program will involve a multi-disciplinary approach and will be incorporated into several curricula/areas at NPS and across the Department of the Navy.

ACQUISITION RESEARCH THROUGH THE ACQUISITION CHAIR AND RESEARCH PROGRAM

Yu-Chu Shen, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: U.S. Army Materiel Command

OBJECTIVE: To perform studies and analysis in acquisition topics; and to stimulate and supervise studies and analyses conducted by faculty and graduate students.

THE EFFECTS OF FUNDING GENEROSITY ON EMERGENCY DEPARTMENT ACCESS AND THE CONSEQUENCES ON PATIENT OUTCOMES

Yu-Chu Shen, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Robert Wood Johnson Foundation

SUMMARY: The ability of public health systems to respond to emergencies, large-scale disasters, and epidemics depends critically on local emergency-services capacity. It is well documented that the U.S. experiences decreased access to emergency departments (ED). However, there is little empirical evidence on its consequences for population health. The principle objectives of this research are twofold: 1) to explore how the variation in public funding sources influence access to ED; and 2) to examine whether decreased ED access (measured by ED closures and ED diversion time) results in adverse patient outcomes or changes.

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THE ANNUAL ACQUISITION RESEARCH SYMPOSIUM – REGISTRATION AND GIFT ACCOUNTS

Keith F. Snider, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Various

OBJECTIVE: To establish accounts and procedures for the development, delivery, and maintenance of the Annual Acquisition Research Symposium of the Naval Postgraduate School.

THE CHAIR OF ACQUISITION MANAGEMENT AND ACQUISITION RESEARCH

Keith F. Snider, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Naval Sea Systems Command

OBJECTIVE: Pursuant to the 28 February 2008 MOU between the Commander, NAVSEA, and the NPS President, NPS proposes to perform studies and analysis in acquisition topics of immediate concern to the commander, as well as to stimulate studies and analysis conducted by faculty and graduate students. Proposed topics will be agreed upon by the sponsor and the Acquisition Research Chair.

THE CHAIR OF ACQUISITION AND THE ACQUISITION RESEARCH PROGRAM

Keith F. Snider, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Naval Air Systems Command

OBJECTIVE: Pursuant to the MOU between the Commander, NAVAIR, and the NPS President, NPS proposes to perform studies and analyses in acquisition topics of immediate concern to the commander, as well as to stimulate studies and analyses conducted by faculty and graduate students. Proposed topics will be agreed upon by the sponsor and the Acquisition Research Chair.

THE CHAIR OF ACQUISITION AND THE ACQUISITION RESEARCH PROGRAM

Keith F. Snider, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Program Executive Office, Integrated Warfare Systems

OBJECTIVE: Pursuant to the 10 October 2007 MOU renewal between PEO (IWS) and the NPS President, NPS proposes to perform studies and analyses in acquisition topics of immediate concern to the PEO, as well as to stimulate and supervise studies and analyses conducted by NPS faculty and students.

THE CHAIR OF ACQUISITION MANAGEMENT AND ACQUISITION RESEARCH

Keith F. Snider, Associate Professor
Graduate School of Business and Public Policy
Sponsor: Naval Air Systems Command

OBJECTIVE: Pursuant to the 24 April 2008 MOU between the Program Manager, NAVAIR PMA-290, and the NPS President, NPS proposes to perform studies and analyses in acquisition topics of immediate concern to the commander, as well as to stimulate studies and analyses conducted by faculty and graduate students. Proposed topics will be agreed upon by the sponsor and the Acquisition Research Chair.

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THE CHAIR OF ACQUISITION MANAGEMENT AND ACQUISITION RESEARCH

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Program Executive Office, Integrated Warfare Systems 7.0

OBJECTIVE: Pursuant to the MOU renewal between PEO (IWS) and the NPS President, dated 10 October 2007, NPS proposes to perform studies and analyses in acquisition topics of immediate concern to the PEO, as well as to stimulate and supervise studies and analyses conducted by NPS faculty and students.

THE CHAIR OF ACQUISITION MANAGEMENT AND THE ACQUISITION RESEARCH PROGRAM

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Program Executive Officer Ships

OBJECTIVE: Pursuant to the MOU between PEO Ships and the NPS President, renewed 29 October 2006, NPS proposes to perform studies and analyses in acquisition topics of immediate concern to the PEO, as well as to stimulate and supervise studies and analyses conducted by NPS faculty and students.

THE CHAIR OF ACQUISITION MANAGEMENT AND AMF JTRS ACQUISITION RESEARCH

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Joint Tactical Radio System Joint Program Executive Office

SUMMARY: AMF JTRS desires to have faculty and students at NPS engaged in acquisition research involving topics that are of importance to the Program Executive Office and the Department of Defense. In furtherance of this objective, AMF JTRS wishes to sponsor research under the Chair of Acquisition Management positioned in the Graduate School of Business and Public Policy at the Naval Postgraduate School.

THE CHAIR OF ACQUISITION MANAGEMENT AND THE OSD-SPONSORED ACQUISITION RESEARCH PROGRAM

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Acquisition Support Center

SUMMARY: The Acquisition Chair is responsible for, among other things, managing acquisition research for the Army and the Naval Postgraduate School (NPS), including coordinating research opportunities for NPS faculty, stimulating research projects by selected graduate students, travel as necessary to support research objectives, and providing seminars and symposiums.

THE CHAIR OF ACQUISITION MANAGEMENT AND THE OSD-SPONSORED ACQUISITION RESEARCH PROGRAM

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Office of the Secretary of the Air Force Acquisition

OBJECTIVE: The Acquisition Chair is responsible for, among other things, managing acquisition research for SAF/AQX and NPS, including coordinating research opportunities for NPS faculty, stimulating research projects by selected graduate students, traveling as necessary to support research objectives, and providing seminars and symposiums. Graduate School of Business and Public Policy faculty and students will undertake specific research projects identified by SAF/AQX, however, if specific

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projects are not delineated, the Acquisition Chair will apply discretion in determining the appropriate scope and depth of research work to be performed. In consultation with SAF/AQX, the Acquisition Chair will continuously develop a list of potential research subjects.

THE CHAIR OF ACQUISITION MANAGEMENT AND SSP ACQUISITION RESEARCH

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Department of the Navy Strategic Systems Programs

OBJECTIVE: The Strategic Systems Program (SSP) desires to have faculty and students at NPS engaged in acquisition research involving topics that are of importance to the Program Executive Office, the Department of the Navy, and the Department of Defense. In furtherance of this objective, SSP wishes to sponsor research under the Chair of Acquisition Management positioned in the Graduate School of Business and Public Policy.

DASN (A&LM) ACQUISITION RESEARCH THROUGH THE ACQUISITION CHAIR AND RESEARCH PROGRAM

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Office of the Assistant Secretary of the Navy

OBJECTIVE: Logistics education opportunities; helping to link acquisition and logistics management education and research at NPS to Department of the Navy/Department of Defense requirements; traveling to and from the offices of DASN (A&LM), NPS, and other activities as necessary to support the educational and research objectives of the chair; and providing quarterly written and/or oral reports to DASN (A&LM) and NPS on research and educational accomplishments if requested.

THE OFFICE OF THE SECRETARY OF DEFENSE-SPONSORED ACQUISITION RESEARCH PROGRAM AT THE NAVAL POSTGRADUATE SCHOOL

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics)

OBJECTIVE: Pursuant to the MOU between the Director of Acquisition Resources and Analysis, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD AT&L) and the President of the Naval Postgraduate School (NPS), NPS proposes to perform acquisition research in support of an Office of the Secretary of Defense-sponsored acquisition research program domiciled at the Naval Postgraduate School.

SUPPORT STUDENT AND ACQUISITION RESEARCH AT THE NAVAL POSTGRADUATE SCHOOL

Keith F. Snider, Associate Professor

Graduate School of Business and Public Policy

Sponsor: Office of the Assistant Secretary of the Army

OBJECTIVE: To support graduate student and acquisition research at the Naval Postgraduate School (NPS). The DDACM represents the sponsor of the Systems Acquisition Management (816) curriculum and the Master of Science in Program Management (836) curriculum. These curricula provide officers and government civilians with an advanced education in the fundamental concepts, methodologies, and analytical techniques necessary for successful acquisition and management of major defense systems.

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BUILDING STRATEGIC COMMUNICATION CAPABILITIES

George W. Thomas, Professor
Graduate School of Business and Public Policy
Sponsor: U.S. Joint Forces Command

OBJECTIVE: To support J9's goals, the Naval Postgraduate School will assist J9 in aligning communication products with the strategic goals of stakeholders. The purpose of the work is to build an internal capability for turning technical documents into products that are easily accessible to a variety of key stakeholders.

LEVERAGED BUYOUT (LBO) AND REVERSE LBO

Chong Wang, Assistant Professor
Graduate School of Business and Public Policy
Sponsor: Naval Postgraduate School

OBJECTIVE: To address a wide range of research questions related to leveraged buyout (LBO) and reverse LBO based on theories in finance and accounting. The principal investigator will generate testable hypotheses and use empirical data to test those projections. The final results will help in understanding the roles played by buyout houses in LBO and reverse-LBO activities. For instance, the questions to be investigated will include, but are not limited to, the following: do private equity firms really enhance value or they just do cosmetic financial engineering? What kind of portfolio companies tend to choose IPO as exit strategy? What factors influence stay-in-private length? Do firms manage earnings before they go to reverse-LBO? How does earnings quality, corporate governance change from pre-LBO to post-reverse-LBO?, etc.

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**2009
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and Presentations**

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INSTITUTES AND CENTERS

**CEBROWSKI INSTITUTE
FOR INFORMATION INNOVATION
AND SUPERIORITY**

**WAYNE E. MEYER INSTITUTE
OF SYSTEMS ENGINEERING**

**MOVES INSTITUTE
(MODELING, VIRTUAL ENVIRONMENTS,
AND SIMULATION)**

**CENTER FOR INTERDISCIPLINARY
REMOTELY PILOTED AIRCRAFT STUDIES**

FIELD EXPERIMENTATION PROGRAM—USSOCOM

NATIONAL SECURITY INSTITUTE

CENTER FOR ASYMMETRIC WARFARE

GLOBAL PUBLIC POLICY ACADEMIC GROUP

**CEBROWSKI INSTITUTE
FOR INFORMATION INNOVATION
AND SUPERIORITY**

**PETER J. DENNING
DIRECTOR**

CEBROWSKI INSTITUTE

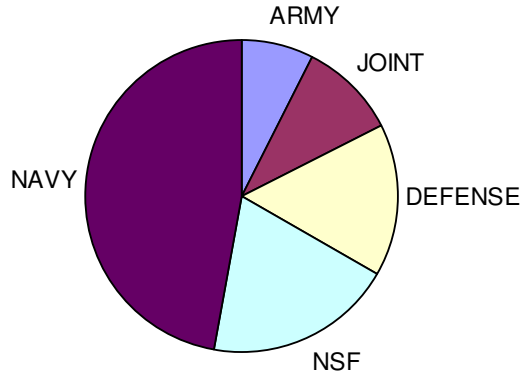
OVERVIEW:

The Cebrowski Institute for Innovation and Information Superiority sponsors cross-discipline investigations into ways that information processes and technologies, organizational development, and personal skills can strengthen stability, transition operations, crisis response, warfighting, and defense in support of national and global security.

Areas of focus include hastily formed networks, indicators of impending crisis, globalization, architectures for network centric operations, World Wide Consortium for the Grid (W2COG), maritime domain awareness, mobile devices and communications, information operations, counterterrorism and irregular warfare, energy and sustainability, information assurance and security, and innovation process.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Cebrowski Institute is provided below:



Size of Program: \$3M

CEBROWSKI INSTITUTE

Peter J. Denning
Director
Department of Computer Science
831-656-3603
pjd@nps.edu

Susan Higgins
Deputy Director, Department
of Information Sciences
831-656-3596
slhiggin@nps.edu

Warren Yu
Chief Learning Officer
831-656-3531
wyu@nps.edu

Wolfgang Baer
Department of Information
Sciences
831-656-2209
baer@nps.edu

Rex A. Buddenberg
Senior Lecturer
Department of Information
Sciences
831-656-3576
budden@nps.edu

William D. Hatch, II
Lecturer
Graduate School of Business
and Public Policy
831-656-2463
wdhatch@nps.edu

Mark Bergman
Assistant Professor
Department of Information
Sciences
831-656-3562
mbergman@nps.edu

Karen Burke
Research Associate Professor
Department of Computer
Science
831-656-3988
klburke@nps.edu

Susan P. Hocevar
Associate Professor
Graduate School of Business
and Public Policy
831-656-2249
shocevar@nps.edu

Dan C. Boger
Chair, Department of
Information Sciences
831-656-3671
dboger@nps.edu

Arijit Das
Research Associate
831-656-3970
adas@nps.edu

Thomas J. Housel
Professor
Department of Information
Sciences
831-656-7657
tjhousel@nps.edu

Alexander Bordetsky
Associate Professor
Department of Information
Sciences
831-656-2287
abordets@nps.edu

Dorothy E. Denning
Distinguished Professor
Department of Defense
Analysis
831-656-3105
dedennin@nps.edu

Patricia A. Jacobs
Professor
Department of Operations
Research
831-656-2258
pjacobs@nps.edu

Donald P. Brutzman
Associate Professor of
Applied Science
831-656-2149
brutzman@nps.edu

George Dinolt
Professor of Practice
Department of Computer
Science
831-656-3889
gwdinolt@nps.edu

Carl R. Jones
Professor Emeritus
Department of Information
Sciences
831-656-2995
cjones@nps.edu

Nancy Ann Budden
Department of Defense
Analysis
831-656-3332
nbudden@nps.edu

John Gibson
Lecturer
Department of Computer
Science
831-656-2902
[jhigibson@nps.edu](mailto:jhgibson@nps.edu)

Moshe Kress
Professor
Department of Operations
Research
831-656-2927
mkress@nps.edu

CEBROWSKI INSTITUTE

Don McGregor
Research Associate
MOVES Institute
831-656-7605
mcgredo@nps.edu

Mark E. Nissen
Professor, C2 Chairman and
Director, Center for Edge
Power
Department of Information
Sciences
831-656-3570
MNissen@nps.edu

Steven E. Pilnick
Research Associate Professor
Wayne E. Meyer Institute of
Systems Engineering and
Department of Operations
Research
831-656-2283
spilnick@nps.edu

Nancy C. Roberts
Professor
Department of Defense
Analysis
831-656-2742
nroberts@nps.edu

Neil Rowe
Professor
Department of Computer
Science
831-656-2462
ncrowe@nps.edu

Weilian Su
Associate Professor
Department of Electrical and
Computer Engineering
831-656-3217
weilian@nps.edu

Roberto Szechtman
Associate Professor
Department of Operations
Research
831-656-3311
rszechtm@nps.edu

Dennis M. Volpano
Associate Professor
831-656-3091
volpano@nps.edu

Geoffrey G. Xie
Professor
Department of Computer
Science
831-656-2693
xie@nps.edu

CEBROWSKI INSTITUTE

CPATH CDEF: RESPARING INNOVATION IN COMPUTING EDUCATION

Peter J. Denning, Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: National Science Foundation

OBJECTIVE: To support U.S. competitiveness by stimulating a greater supply of talented, innovative, young people in computing. Our claim is that the current “operating model” for the computing curriculum is outdated: prospective students find more value in other curricula. This project aims to design a new operating model and, with support from the ACM education board, get CS&E departments to experiment with the model. The new model will be true to fundamental computing principles, emphasize innovation by individual faculty, students, and departments, and support faculty in their roles as mentors and coaches. These objectives will be realized through three workshops and a final report. A key aspect is that the project will design support networks and structures that can be administered by ACM to sustain ideas from the workshops.

TRANSFORMATIONAL C2 SERVICES FOR UNDERSTANDING THE IMPACT OF GLOBALIZATION ON STABILITY AND SECURITY

Peter J. Denning, Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Space and Naval Warfare Systems Center-Charleston

OBJECTIVE: To establish a collaboration laboratory (Co-Lab) focused on open technology development initiatives and their potential impact on issues of globalization, stability, and security. Co-Lab will provide a venue for exploring best practices across disciplines regarding open-source community engagement and technology development between collaborators.

THE JOINT INTEROPERABILITY TEST COMMAND NETCENTRIC CERTIFICATION OFFICE

Christopher Gunderson, Research Associate Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Joint Interoperability Test Command

OBJECTIVE: To establish a U.S. Government Netcentric Certification Office for performing embedded test, evaluation, certification, accreditation, and validation and verification of network services.

A NETCENTRIC CERTIFICATION OFFICE

Christopher Gunderson, Research Associate Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Defense Information Systems Agency

OBJECTIVE: To establish a U.S. Government Netcentric Certification Office for performing embedded test, evaluation, certification, accreditation, and validation and verification of network services.

A NETCENTRIC CERTIFICATION OFFICE

Christopher Gunderson, Research Associate Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Joint Interoperability Test Command

OBJECTIVE: To establish a U.S. Government Certification Office for performing embedded test, evaluation, certification, accreditation, and validation and verification of network services.

CEBROWSKI INSTITUTE

A COMPLEX-OPERATIONS CASE-STUDY SERIES

Karen Guttieri, Assistant Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Office of the Secretary of Defense

SUMMARY: Concept development and production of a complex-operations case-study series.

THE MONTEREY CULTURAL EDUCATION SYMPOSIUM

Karen Guttieri, Assistant Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Naval Postgraduate School

OBJECTIVE: To develop and execute a cultural-education film symposium on the Monterey Peninsula. After viewing each film, a panel discussion of regional and local experts will discuss the significance of the films to the greater missions of the Department of Defense (DoD) and within the context of U.S. foreign policy. While open to the public, the primary audience will be military practitioners from the Naval Postgraduate School, the U.S. Army College, the Defense Language Institute, and students from the Monterey Institute of International Studies. The films are donated by the Corporation for Public Broadcasting and present internationally recognized films focused on human rights, democracy and elections, economic development, conflict resolution, poverty, war and conflict, and cultural awareness. Where possible, introductions in the language of the film will be made, and there is potential for recording and redistribution for Navy personnel deployed at sea. Public forums will be open to all interested in widening and deepening their understanding of human rights and global development.

RECOGNIZING PATTERNS OF ANOMIE THAT SET THE CONDITIONS FOR INSURGENCY

Karen Guttieri, Assistant Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Office of Naval Research

OBJECTIVE: To better understand and depict how social unrest leads to insurgencies in order to develop better decision-making options. This work will better prepare civilian and military decision-making for future insurgencies in places of unrest by compiling scientific evidence for cause-targeted interventions aimed at anticipating and mitigating societal disorder. If instability-related patterns and risks of societal disorder are to be detected and reversed in time, it is crucial to perform an in-depth assessment of invisible but measurable attitudes that precede subsequently observable patterns of behavior. Researchers seek to detect relevant correlations and interactions between social change and societal disorder at an early stage, as well as to identify the potential for sustainable order.

A RESEARCH AND CURRICULUM DEVELOPMENT PROJECT

Karen Guttieri, Assistant Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Peacekeeping and Stability Operations Institute

OBJECTIVE: To launch a systematic research program designed to build the body of knowledge on peacekeeping and stability operations at the Peacekeeping and Stability Operations Institute (PKSOI). The research agenda encompasses prevention, counterinsurgency, and disaster assistance, as well as transition and reconstruction activities (security, stability, transition, and reconstruction or SSTR). Research and curriculum development a PKSOI and the Naval Postgraduate School will advance shared interests to address the challenges of globalization, stability, and security.

CEBROWSKI INSTITUTE

A RESEARCH AND CURRICULUM DEVELOPMENT PROJECT

Karen Guttieri, Assistant Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: U.S. Army War College

OBJECTIVE: To launch a systematic research program designed to build the body of knowledge on peacekeeping and stability operations at the Peacekeeping and Stability Operations Institute (PKSOI). The research agenda encompasses prevention, counterinsurgency, and disaster assistance, as well as transition and reconstruction activities (security, stability, transition, and reconstruction or SSTR). Research and curriculum development at PKSOI and the Naval Postgraduate School will advance shared interests to address the challenges of globalization, stability, and security.

RESEARCH SUPPORT FOR HYBRID KNOWLEDGE FRAMEWORK FOR COMPLEX OPERATIONS (HYKNOCO)

Karen Guttieri, Assistant Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Office of Naval Research

OBJECTIVE: To provide research-panel support for the Milcord, L.L.C., development of a semantic and structured wiki service that will serve the information and knowledge management needs of the complex operations community responsible for mission training, planning, and operations. The HYKNOCO Project by Milcord, L.L.C., of which this proposal is a part, seeks to research, design, and develop a hybrid-answers engines prototype. This proposal responds to the BAA objectives for an “effects and open-source reliability scoring capability, integrating fact and opinion-based knowledge sources.” The overall project goal is to build the application using open-source semantic wiki tools (e.g., Semantic Media Wiki) for knowledge representation, open-source structured wiki tools (e.g., TikiWiki) for structured content representation, and our knowledge management (CKM) framework for fact discovery and management. Open-source knowledge and data sources (e.g., doctrine manuals, encyclopedia knowledge, historical databases, and current news) will be used to build a sufficiently rich application that will attract community participation in order to grow the machine-extracted knowledge with user participation.

BANDWIDTH ALLOCATION MANAGEMENT

Susan Higgins, Deputy Director

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Program Executive Office Command, Control, Communications, Computers, and Intelligence

OBJECTIVE: To determine the need and formulate potentially useful bandwidth-management techniques through research, interviews, and seminar war-gaming. The study will be coordinated with other modeling activities conducted by other vendors.

DISRUPTIVE TECHNOLOGY EXPLORATION

Susan Higgins, Deputy Director

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Office of Naval Research

OBJECTIVE: To identify, evaluate, and provide recommendations on how emerging/disruptive business technologies and alternate business models can be leveraged to innovate business operations and support improved time-to-value realization of capabilities to the enterprise.

CEBROWSKI INSTITUTE

AN ENERGY CONVERSATION

Susan Higgins, Deputy Director

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Office of Naval Research

OBJECTIVE: To support the growth and development of a cross-government community that raises awareness of the importance of energy and sustainability for national security and national well-being; to explore requirements for growing a robust, cross-governmental, information-sharing capacity on the topics of energy and sustainable practices.

STRATEGIC CHANGE COMMUNICATIONS

Susan Higgins, Deputy Director

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Office of Naval Research

OBJECTIVE: To develop capacity at the Office of Naval Research to meet customer needs through action-oriented research in strategic change communications. Included is the development of a systematic approach to communication through strategic engagement with a wide range of stakeholders.

CDLS REVIEW

Scot Miller, Research Associate Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To identify, evaluate, and provide recommendations on how emerging/disruptive business technologies and alternate business models can be leveraged to innovate business operations and support improved time-to-value realization of capabilities to the enterprise.

THE GLOBAL WARGAME 2009 SPAWAR ENGAGEMENT TASK

Scot Miller, Research Associate Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To attend the Initial, Middle, and Final Planning Conferences and the actual Global 2009 War Game. To ensure that proper representation of SPAWAR C5I systems' operational capabilities and planned capabilities are modeled appropriately in the war game. Through observation and interaction, to gain insight into emerging force structure and C5I requirements for the time frame being played in the game. To prepare recommendations to SPAWAR leadership based on these observations.

HASTILY FORMED NETWORKS IN SUPPORT OF HUMANITARIAN ASSISTANCE/DISASTER RELIEF AND STABILITY, SECURITY, TRANSITION, AND RECONSTRUCTION OPERATIONS

Brian D. Steckler, Professor

Cebrowski Institute for Information Innovation and Superiority

Sponsor: Office of the Secretary of Defense for Networks and Information Integration

SUMMARY: OASD-NII (ITS) desires to continue sponsoring Naval Postgraduate School (NPS) studies focused on the full range of hastily formed networks (HFN) activities, from the earliest stages (finding ways to bring the participating parties into a mode of cooperation and trust quickly) to a mature/functional HFN in the field. NPS students will deliver Master's thesis projects to meet the goals of these studies. NPS faculty and student teams will deliver after-action reports and/or case studies as appropriate. NPS faculty and students will consider issues such as preparatory training, overcoming organizational biases and

conditioned tendencies, technologies to facilitate information sharing, agreements on decision-making and coordination, and involvement of citizens, industry, and civilian and military entities. The topic areas to be covered by these studies will be agreed upon in discussions between the principal investigator and the OASD-NII (ITS) point of contact.

**CEBROWSKI INSTITUTE
FOR INFORMATION
INNOVATION AND
SUPERIORITY**

**2009
Faculty Publications
and Presentations**

CEBROWSKI INSTITUTE

Publications and presentations for Cebrowski Institute faculty members are listed in their respective home departments.

**WAYNE E. MEYER INSTITUTE
OF SYSTEMS ENGINEERING**

**PAUL V. SHEBALIN
RADM, USNR (RET.)
DIRECTOR**

WAYNE E. MEYER INSTITUTE OF SYSTEMS ENGINEERING

OVERVIEW:

The Wayne E. Meyer Institute of Systems Engineering was first established as the Institute of Defense Systems Engineering and Analysis in 2001. In May 2002, the Institute was renamed the Wayne E. Meyer Institute of Systems Engineering after RADM Wayne E. Meyer, USN (Ret.), the founding Program Manager of the Aegis Combat System, the first large Navy Surface Warfare acquisition program in which a total systems approach was used in system development and design.

The mission of the Institute is to provide relevant, tailored, and unique research opportunities in systems engineering to support Naval Postgraduate School (NPS) graduate education that increases the combat effectiveness of U.S. and allied armed forces and enhances the security of the United States.

FUNCTIONS:

In meeting the priority needs of our national security stakeholders, the Meyer Institute currently has the following functions:

- Establish and conduct NPS-wide programs in systems engineering research for the Navy, the Department of Defense, and other national security customers that require interdisciplinary teams.
- Foster and encourage all NPS faculty and students to apply their talents to answering the high priority questions in defense systems engineering.
- Support, facilitate, and enable faculty and students affiliated with the Meyer Institute to conduct sponsored research in defense systems engineering.
- Publicize and share the results of NPS defense systems engineering research.
- Support the assigned Chair Professors – enable the Warfare Chairs and PEO-, Industry-, and other sponsored chair professors to carry out their academic responsibilities.

RESEARCH:

Research supported over the last seven years:

- Twelve Systems Engineering and Analysis student capstone, interdisciplinary research projects in such areas as littoral undersea warfare, port security, and ship-based ABM
- Littoral Oceanography for Mine Warfare
- Attrition Models for Unmanned Systems
- Deployable Joint Command and Control
- Navy Ship Design
- Safety and Risk-Informed Decision-Making
- Impact Burial Prediction
- Chinese Oceanographic Research
- Technological Surprise in Nuclear Physics
- MDA Field Sensor Experimentation
- Port Security

RESEARCH FACILITIES:

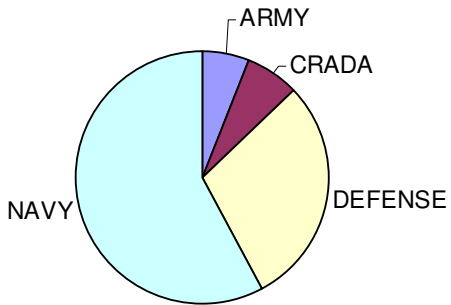
The research facilities that support faculty and students include:

- Faculty offices
- Three integrated student design labs
- Research and study space for 44 students

WAYNE E. MEYER INSTITUTE OF SYSTEMS ENGINEERING

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Meyer Institute of Systems Engineering is provided below:



Size of Program: \$1.5M

WAYNE E. MEYER INSTITUTE OF SYSTEMS ENGINEERING

Paul V. Shebalin
Director
Senior Lecturer, Department of Systems Engineering
831-656-1047
pshebali@nps.edu

Irfan Ullah Chaudhary
242-586-4202
irfanc@alum.mit.edu

Peter C. Chu
Professor
Department of Oceanography
831-656-3688
pcchu@nps.edu

Winford G. (Jerry) Ellis
RADM, USN (Ret.)
Professor and Undersea
Warfare Chair
Director, Undersea Warfare
Research Center
831-656-2488
wgellis@nps.edu

Peter L. Hagelstein
Visiting Professor
831-656-7845
PLH@MIT.edu

Rodney W. Johnson
Research Professor
831-656-7959
rwjohnso@nps.edu

Fernand D. Marquis
Research Professor
831-656-3721
fdmarqui@nps.edu

Michael E. Melich
Research Professor
831-656-1776
mmelich@nps.edu

David H. Olwell
Professor
Department of Systems
Engineering
831-656-3583
dholwell@nps.edu

William D. (Will) Rodriguez
Deputy Director
831-656-2371
wdrodrig@nps.edu

William A. Solitario
Northrop Grumman Chair of
Systems Engineering
831-656-2546
wasolita@nps.edu

Richard (Rick) Williams
Chair of Mine Warfare
831-656-7702
rdwillia@nps.edu

WAYNE E. MEYER INSTITUTE OF SYSTEMS ENGINEERING

MODELING AND SIMULATION OF ACOUSTIC SONAR TRANSDUCER ARRAY ELEMENTS AND THEIR INTERACTION

Steven R. Baker, Associate Professor

Wayne E. Meyer Institute of Systems Engineering

Sponsor: L-3 Communications Corporation-Ocean Systems

OBJECTIVE: To improve the ability to numerically model the acoustic interactions between sonar transducers such as are or may be employed by L-3 in an active dipping sonar system, particularly as these transducers might be arranged in close-packed clusters. For example, it is desired to be able to predict the effect of their interaction on resonance frequency, bandwidth, and transmit-source level.

WAVE EFFECT ON UNDERWATER BOMB TRAJECTORY AND TAIL SEPARATION

Peter C. Chu, Professor

Wayne E. Meyer Institute of Systems Engineering

Sponsor: Office of Naval Research

OBJECTIVE: A question has been raised about the possible impact sea state may have on the performance of JABS in the very shallow water (VSW) regime (depth up to 40 feet). The purpose of this project is to investigate the wave effect on underwater bomb trajectory and tail separation.

THE NAVAL POSTGRADUATE SCHOOL CHAIR OF UNDERSEA WARFARE PROGRAM

Jerry Ellis, Chair of Undersea Warfare

Wayne E. Meyer Institute of Systems Engineering

Sponsor: Naval Undersea Warfare Center-Newport Division

SUMMARY: The Chair of Undersea Warfare was established with an MOU between the president of the Naval Postgraduate School (NPS) and the Newport Undersea Warfare Center (NUWC) Commander. The chair program is intended to enhance the academic and research content in several curricula with undersea warfare-related material and to establish NPS as a major center for instruction, research, and analysis in undersea warfare subjects. To that end, the chair serves as the Director, NPS Undersea Warfare Research Center. The function is under the NPS Wayne E. Meyer Institute of Systems Engineering. Parties to the Chair of Undersea Warfare MOU agreed that the position be established on a continuing basis to support undersea warfare acquisition and life-cycle management. This proposal supports the continuing employment agreement for RADM R.G. Jones, USN (Ret.), the hiring agreement for RADM Winford Ellis, USN (Ret.), and travel expenses required by the Chair of USW.

UNDERSEA WARFARE RESEARCH SUPPORT

Jerry Ellis, Chair of Undersea Warfare

Wayne E. Meyer Institute of Systems Engineering

Sponsor: Chief of Naval Operations, N87/N85

OBJECTIVE: To increase the research opportunities that result in improving the quality of undersea warfare-related courses at the Naval Postgraduate School.

WAYNE E. MEYER INSTITUTE OF SYSTEMS ENGINEERING

THE DEVELOPMENT OF A NAVAL SIMULATION SYSTEM OPERATIONAL-LEVEL ASW SCENARIO

Jeffrey E. Kline, Senior Lecturer
Department of Operations Research
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To produce, develop, and create an operational-level area-antisubmarine scenario within the classified Naval Simulation System at the Naval Postgraduate School to enable faculty and students from the Undersea Warfare, Operations Research, Operations Logistics, Systems Engineering, Combat Systems, MOVES, and Systems Engineering and Analysis curricula to conduct research and evaluation on the impacts of technology advancements and concept-of-operation changes to an area ASW scenario. The scenario will be based on a near-peer competitor with advanced, maritime, anti-access capabilities.

AEROSOL DUCT SEALING TECHNOLOGY

Fernand D.S. Marquis, Research Professor
Wayne E. Meyer Institute of Systems Engineering
Sponsor: NAVFAC Command

SUMMARY: In heated or cooled spaces, ductwork is often used to channel conditioned air to its required location. Heating and cooling costs of a facility are increased due to this ductwork leaking air into unconditioned spaces, such as attics and mechanical rooms. Only through sealing the leaks can these effects be minimized. This duct sealing technology attempts to seal the cracks and leaks in existing ductwork by injecting a fog of aerosolized sealant particles into a pressurized duct system. Hence, equivalent building conditions can be maintained with a lower energy input. This research focuses on the transfer and on the application of this new technology to four Navy installations (multiple buildings for each site): 1) Naval Air Station Joint Reserve Base (NAS JRB) Forth Worth, 2) Navy Base Bremerton, Washington, 3) Navy Station Newport, and 4) Navy Support Activity MidSouth. In addition, this work is designed to quantitatively evaluate the impact of the application of this technology to Navy Facilities and to extrapolate this impact to Department of Defense facilities.

EXTERNAL INSULATION FINISHING SYSTEMS

Fernand D.S. Marquis, Research Professor
Wayne E. Meyer Institute of Systems Engineering
Sponsor: NAVFAC Command

OBJECTIVE: External Insulation Finishing Systems (EIFS) are complex material systems consisting of many layered components, such as foam boards (polystyrene or styrofoam, polyisocyanurate), structural fabrics and metal grids, moisture barriers, and others. These components are attached to each other and to the exterior wall using adhesives and fasteners. The new exterior surfaces are finished with water resistant vinyl-cement coatings, and/or nanostructured coatings (some of them using the lotus effect) that can be colored, molded, and textured. These systems need to be tailor-designed to different types of constructions, environments, and climatic conditions and will save energy by decreasing the use of the buildings' air conditioning and/or heating system. This research focuses on the transfer and on the application of this new technology to four Navy installations (one building for each site): 1) Naval Air Weapons Station (NA WS) China Lake; 2) Naval Support Facility (NSF) Dahlgren; 3) Naval Undersea Warfare Center (NUWS) Keyport, Washington, and 4) Naval Air Station Joint Reserve Base (NAS.JRB) New Orleans. In addition, this work is designed to quantitatively evaluate the impact of the application of this technology to Navy facilities and to extrapolate this impact to Department of Defense facilities.

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NANOFLUID NANOTECHNOLOGY AND PHASE-CHANGE MATERIALS NANOTECHNOLOGY

Fernand D.S. Marquis, Research Professor
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Northrop Grumman Electronic Systems

OBJECTIVE: This research will focus on the development of thermal management systems for mobile, directed-energy weapons (DEWs) utilizing solid state lasers (SSLs). The goals are to simultaneously enable the very high-amount and the very high-rate of heat removal. This will simultaneously enable a high-power and low transient system to be developed. This work has two parts: a) nanofluid nanotechnology for the primary loop, and b) phase-change materials nanotechnology for thermal-energy storage systems. This is the continuation of work funded by a CRADA with Northrop Grumman Electronic Systems with multiple applications to several energy systems.

POLYMER-BASED NANOCOMPOSITES AND HYBRID MATERIALS FOR NAVAL APPLICATIONS

Fernand D.S. Marquis, Research Professor
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Northrop Grumman Ship Systems

OBJECTIVE: This research will focus on the development of hybrid nanocomposites, which will be able to increase the strength, stiffness, shock resistance, and fire resistance of localized naval structures. In addition, it is expected that specific thermal and electromagnetic properties could be acquired with potential to significant multi-functional applications, including potential changes in signature of the localized structure. This is the continuation of work funded by a CRADA with Northrop Grumman Ship Systems with multiple applications to several renewable energy systems.

THE TECHNOLOGY TRANSFER OF NEW TECHNOLOGIES

Fernand D.S. Marquis, Research Professor
Wayne E. Meyer Institute of Systems Engineering
Sponsor: NAVFAC Command

SUMMARY: This research focuses on the transfer and on the application of new technologies to Navy Facilities. There are a few new technologies that we are currently focusing on. However my primary responsibility is with thermal insulation materials and systems. These are complex material systems with many interfaces that need to be tailored to different environments. These are similar to discontinuous functional gradient material systems. We are currently developing these materials for applications in China Lake, New Orleans, Dahlgren, Keyport and possibly Bangor.

CRITICAL EXPERIMENTS IN CONDENSED MATTER NUCLEAR SCIENCE, PHASE 2: STANDARD HEAT

Michael E. Melich, Research Professor of Physics
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To experimentally verify the heat-producing performance of three experiments in which electrolytically co-deposited deuterium and palladium have been shown to produce excess heat as measured by a calorimeter. To analyze the experimental results and design a co-deposition cell core and a calorimeter that could improve the experimental yield of the Fleischmann-Pons effect heat experiments.

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CRITICAL EXPERIMENTS IN CONDENSED MATTER NUCLEAR SCIENCE, PHASE 2: STANDARD HEAT

Michael E. Melich, Research Professor of Physics
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: The existence of effects of the condensed matter state on the state of nuclei has been established in a continuing series of experiments begun nearly 20 years ago. It has become clear that the release of nuclear energy in these chemical systems depends upon subtle correlation effects created within the condensed matter state, particularly where hydrogen is loaded into metals. A workshop was conducted 25-28 October 2006 at the Naval Research Laboratory.

A review of the experimental evidence was conducted and areas of fruitful research were identified. Since the workshop, the Defense Threat Reduction Agency (DTRA) has identified the engineering of a heat production experiment as the vehicle for expanding the understanding of the basic physical processes. Inferencing methods will be used for building phenomenological models from experimental evidence to organize the analysis of the standard experiment. Workshops to consolidate the DTRA co-deposition standard experiments will be organized.

CRITICAL EXPERIMENTS IN CONDENSED MATTER NUCLEAR SCIENCE, PHASE 2B: STANDARD HEAT EXPERIMENT MODELING AND ANALYSIS

Michael E. Melich, Research Professor of Physics
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Defense Threat Reduction Agency, Naval Research Laboratory

OBJECTIVE: That the condensed matter state affects the state of nuclei has been established in a continuing series of experiments begun nearly 20 years ago. It has become clear that the release of nuclear energy in these chemical systems depends on subtle correlation effects in the condensed matter state, particularly where hydrogen is loaded into metals. A workshop was conducted 25-28 October 2006 at the Naval Research Laboratory, where the experimental evidence was reviewed and areas of fruitful research were identified. Subsequently, the Defense Threat Reduction Agency (DTRA) identified the Fleischmann-Pons Effect (FPE), i.e., heat-producing experiments, as a focus. Inference methods (Bayesian networks) were developed for assessing the weight of evidence for FPE from multiple sources. These will be extended to characterize sources of error in ongoing experiments and to suggest where improvements and further experimentation could contribute to the reliability of the results. An Institute for Condensed-Matter Nuclear Science (CMNS) Theory will be established to study, in collaboration with visiting scientists, a number of proposed theoretical mechanisms and the connection of the experimental evidence therewith.

CRITICAL EXPERIMENTS IN CONDENSED MATTER NUCLEAR SCIENCE, PHASE 2B: STANDARD HEAT EXPERIMENT MODELING AND ANALYSIS

Michael E. Melich, Research Professor
Rodney W. Johnson, Research Professor
Wayne E. Meyer Institute of Systems Engineering
(Joint with Naval Research Laboratory-Naval Center for Space Technology)
Sponsor: Defense Threat Reduction Agency

OBJECTIVE: This is Phase 2b of work begun in 2006. The existence of effects of the condensed matter state on the state of nuclei has been established in a continuing series of experiments begun over 20 years ago. It has become clear that the release of energy in these chemical systems depends upon subtle correlation effects within the condensed matter state, particularly where hydrogen is loaded into metals. A workshop was conducted during 25-28 October 2006 at NRL, where a review of the experimental evidence was conducted and areas of fruitful research were identified. Subsequently, DTRA identified the Fleischmann-Pons Effect (FPE), i.e., heat-producing experiments, as a focus.

An objective of this work is to use formal inference methods (in particular Bayesian networks) to characterize sources of error in experiments and to suggest areas for improvement and further

experimentation. A further objective is to organize an Institute for Condensed-Matter Nuclear Science (CMNS) Theory to study, in collaboration with visiting scientists, a number of proposed theoretical mechanisms and their connection with the experimental evidence.

SUMMARY: The investigators prepared for publication a paper (Melich and Johnson, below) on the application of Bayesian networks to the assessment of a selection of published accounts of experiments on the FPE. An informal Institute for CMNS Theory was organized. This brought Professors Peter Hagelstein, of MIT, and Irfan Chaudhary, of the University of Engineering and Technology, Lahore, to NPS as visiting scientists for nearly eight months; and established the value of a central clearing-house for the development of the models and theories that will systematize the understanding of these complex systems. Two workshops were held, each bringing together about a dozen scientists for a shorter period: "Modeling CMNS Experiments and Theoretical Mechanisms" (March) and "Results of Modeling FPE Systems and the Role of Transition Metal Catalysts" (August).

PUBLICATIONS:

Hagelstein, P.L., Melich, M.E., and Johnson, R.W., "Input to Theory from Experiment in the Fleischmann-Pons Effect," *Proceedings of the 14th International Conference on Condensed Matter Nuclear Science (ICCF-14)*, Washington, D.C., 10-15 August 2008.

Hagelstein, P.L., Chaudhary, I., Melich, M.E., and Johnson, R.W., "A Theoretical Formulation for Problems in Condensed Matter Nuclear Science," *Proceedings of the 14th International Conference on Condensed Matter Nuclear Science (ICCF-14)*, Washington, D.C., 10-15 August 2008.

Johnson, R.W. and Melich, M.E., "Weight of Evidence for the Fleischmann-Pons Effect," *Proceedings of the 14th International Conference on Condensed Matter Nuclear Science (ICCF-14)*, Washington, D.C., 10-15 August 2008.

Lipson, A., Chemov, I., Roussetski, A., Cherdantsev, Y., Lider, A., Lyakhov, B., et al., "Charged Particle Emissions during Electron Beam Excitation of Deuterium Subsystem in Pd and Ti-Deuteride Targets," *Proceedings of the 14th International Conference on Condensed Matter Nuclear Science (ICCF-14)*, Washington, D.C., 10-15 August 2008.

KEYWORDS: Condensed-Matter Nuclear Reaction, Low-Energy Nuclear Reaction, Fleischmann-Pons Effect, Cold Fusion, Bayesian

REDUCING THE BARRIERS-TO-RESEARCH INTO THE FLEISCHMANN-PONS EFFECT: PHASE 2 – PRODUCE, TEST, AND CHARACTERIZE THE SYSTEM FOR A PEER- REVIEWED, PUBLISHABLE INSTRUMENTATION PAPER

Michael E. Melich, Research Professor

Rodney W. Johnson, Research Professor

Wayne E. Meyer Institute of Systems Engineering

(Joint with Naval Research Laboratory Code 6503)

Sponsor: Defense Threat Reduction Agency

OBJECTIVE: This is phase two of work begun in December 2007. Phase one: experimentally verify the heat-producing performance of several experiments in which electrolytically co-deposited deuterium and palladium produce excess heat. Select and qualify the preferred co-deposition experiment. Phase two: produce, test, refine, and characterize the selected experiment as a basis for a peer-reviewed paper for publication in a major scientific instrumentation journal.

SUMMARY: Energy and power densities observed by numerous experimenters on the Fleischmann-Pons Effect (FPE) over the last 20 years are persuasive evidence of a real physical effect in deuterium-palladium (D-Pd) systems. However, the multi-week-long time requirements and metallurgical difficulties of preparing a suitable system have been a formidable barrier to scientists interested in investigating the

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effect. Experiments with simultaneous co-deposition of D and Pd on a substrate have suggested that that approach may avoid these problems and may allow the startup time of weeks or months to be reduced to hours or weeks. In response to a challenge from DTRA, an informal workshop was held in September 2007 at SPAWAR Systems Center (SSC) to plan the development of a “standard experiment” that could be published in a reputable journal and could lower the barriers to research on the FPE. Subsequently, three reported experiments were selected as possible bases for development. The first experimental protocol published on this subject was reported by Szpak, et al., in 1991, and for this project was repeated by Dennis Cravens. The second, developed by Miles in Japan at the New Hydrogen Energy Project in 1997-98, is reported in several papers stating that in three out of three codeposition experiments, an excess power of 750 milliwatts was measured. The third codeposition experiment, using the Szpak chemistry but with a gold cathode, was developed by Dennis Letts. NRL has performed the Miles experiment in its calorimeters and has done extensive chemical analysis that has suggested that much of the power observed could be explained chemically. Miles’s experiments suggest that only a small fraction of the observed energy can be attributed to chemical reactions. Work continues to resolve this matter. The Cravens replication of the Szpak experiment did not demonstrate the presence of an excess power beyond chemistry. The Letts experiment seems to consistently show an excess power that when integrated over a long experimental time produces more energy than can be attributed to chemistry. Instrumentation issues with new calorimeters and methods are still being studied to resolve the source of the excess energy.

PUBLICATIONS:

Final reports are being drafted on the work to date by the various experimental groups.

PRESENTATION:

ICCF-14 August 2008 Proceedings. To be published as papers in the March 2010 *Proceedings* volume.

KEYWORDS: Condensed-Matter Nuclear Reaction, Low-Energy Nuclear Reaction, Fleischmann-Pons Effect, Cold Fusion, Codeposition

THE INTEGRATED TOPSIDE STUDY

Fotis A. Papoulias, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: To provide studies related to the Office of Naval Research’s Integrated Topside Innovative Naval Prototype Program as outlined in the statement of work.

NAVY SHIP DESIGN

Fotis A. Papoulias, Associate Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Northrop Grumman Ship Systems, Inc.

ADVANCED TECHNOLOGY INTEGRATION AND ASSESSMENT FOR WARFARE EFFECTIVENESS

Paul Shebalin, RADM, USNR (Ret.), Director
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Northrop Grumman Ship Systems, Inc.

OBJECTIVE: To develop and assess advanced technologies and concepts of operations in the areas of Navy Sea Shield, Sea Strike Pillars, and expeditionary warfare elements. This collaborative research effort is expected to improve future war-fighting missions. Initial focus areas will include a) thermal management, b) ship systems engineering, and c) model-based systems engineering.

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A DEMONSTRATION OF EXTERIOR INSULATION TECHNOLOGY AT DEPARTMENT OF THE NAVY FACILITIES

Paul Shebalin, RADM, USNR (Ret.), Director
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Naval Facilities Engineering Command

OBJECTIVE: Typical and most frequently used exterior insulation consists of foam boards (various types, i.e., polystyrene or styrofoam, polyisocyanurate) that are glued to the exterior wall using a vinyl adhesive. The new exterior surface is finished with a water-resistant vinyl-cement coating that can be colored, molded, and textured similarly to stucco. The objective of this project is to prove that exterior insulation is a cost-effective technology that, if installed in Navy facilities, will help the Navy meet its energy reduction goals. Exterior insulation should reduce energy use without any maintenance issues and with a simple payback of less than 10 years.

THE NAVAL POSTGRADUATE SCHOOL NET-CENTRIC ENTERPRISE SYSTEMS ENGINEERING RESEARCH PROGRAM

Paul Shebalin, RADM, USNR (Ret.), Director
Wayne E. Meyer Institute of Systems Engineering
Sponsor: PEO Enterprise Information Systems

OBJECTIVE: To establish a net-centric systems engineering (NCSE) research capability at the Naval Postgraduate school (NPS) to support the PEO EN and the Navy in the acquisition and deployment of next-generation enterprise and C4I systems. In order to do this, six tasks will be carried out: 1) investigate and document the NCSE and enterprise competencies required by the Navy acquisition and systems engineering workforce; 2) based on these identified workforce competencies, design a set of research-enabled courses and propose adjustments to the NPS NCSE curricula; 3) identify the laboratory requirements for the proposed NCSE courses and design a balanced approach to classroom lecture and laboratory research for each of the specified NCSE courses; 4) design and implement an initial set of expandable lab facilities required for support to the NPS NCSE faculty and students; 5) identify a set of NCSE graduate student capstone project and thesis topics; and 6) develop an FY09-to-FY13 NCSE academic plan that will serve as the basis for NPS NCSE research and education planning.

PORT SECURITY

Paul Shebalin, RADM, USNR (Ret.), Director
Wayne E. Meyer Institute of Systems Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: To develop methodologies and analyses for assessing port-security threat levels, risk assessments, organizational roles, and investment strategies for improving port security. Researchers propose a comprehensive, integrated project that draws on the combined strengths and capabilities of each participant to address the problem of port security in a multidisciplinary format.

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**2009
Faculty Publications
and Presentations**

JOURNALS

Ellis, W.G., "The Re-Emergence of ASW as a High Priority in the U.S. Navy," *Naval Submarine League Review*, Winter 2009.

Lipson, A., Chernov, I., Roussetski, A., Cherdantsev, Y., Tsivadze, A., Lyakhov, B., et al., "'Hot' Deuteron Generation and Charged Particle Emission during Excitation of the Deuterium Subsystem in Metal Deuterides," *Low-Energy Nuclear Reactions and New Energy Technologies Sourcebook*, Vol. 2, Ch. 6, pp. 95-117, Washington, D.C.: American Chemical Society, 2009.

CONFERENCE PUBLICATIONS

Hagelstein, P.L., Melich, M.E., and Johnson, R.W., "Input to Theory from Experiment in the Fleischmann-Pons Effect," *Proceedings of the 14th International Conference on Condensed Matter Nuclear Science (ICCF-14)*, Washington, D.C., 10-15 August 2008.

Hagelstein, P.L., Chaudhary, I., Melich, M.E., and Johnson, R.W., "A Theoretical Formulation for Problems in Condensed Matter Nuclear Science," *Proceedings of the 14th International Conference on Condensed Matter Nuclear Science (ICCF-14)*, Washington, D.C., 10-15 August 2008.

Johnson, R.W. and Melich, M.E., "Weight of Evidence for the Fleischmann-Pons Effect," *Proceedings of the 14th International Conference on Condensed Matter Nuclear Science (ICCF-14)*, Washington, D.C., 10-15 August 2008.

Lipson, A., Chernov, I., Roussetski, A., Cherdantsev, Y., Lider, A., Lyakhov, B., et al., "Charged Particle Emissions during Electron Beam Excitation of Deuterium Subsystem in Pd and Ti-Deuteride Targets," *Proceedings of the 14th International Conference on Condensed Matter Nuclear Science (ICCF-14)*, Washington, D.C., 10-15 August 2008.

PRESENTATIONS

Ellis, W.G., "Unmanned Vehicles in the Navy," presented to ADM (Ret.) Hank Mauz, 2009.

Knies, D.L., Grabowski, K.S., Nguyen, V.K., and Melich, M.E., "The Development of a Low Cost Differential Thermal Analysis System at the Naval Research Laboratory," 15th International Conference on Condensed Matter Nuclear Science (ICCF-15), Rome, Italy, 5-9 October 2009.

Lipson, A., Chernov, I., Roussetski, A., Cherdantsev, Y., Lyakhov, B., Mironchik, V., et al., "Charged Particle Emissions and Surface Morphology of the PdPdO:Dx and the TiDx Targets under an Electron Beam Excitation," 15th International Conference on Condensed Matter Nuclear Science (ICCF-15), Rome, Italy, 5-9 October 2009.

Lipson, A., Chernov, I., Roussetski, A., Tsivadze, A., Lyakhov, B., Cherdantsev, Y., et al., "'Hot' Deuteron Generation and Charged Particle Emission during Excitation of the Deuterium Subsystem in Metal Deuterides," 237th ACS National Meeting, Salt Lake City, Utah, 22-26 March 2009.

Marquis, F.D.S., Primary U.S. Organizer of the Pacific Rim International Conference on Advanced Materials and Processes (PRICM7), Cairns Australia August 1-5, 2010. (Plan to introduce into the program "Multi Level System Design of Materials and Structures." This meeting is organized in rotation by one of the five Pacific Rim countries: U.S., China, Japan, Korea, and Australia.)

Marquis, F.D.S., Session Organizer of the First TMS/ABM (U.S./Brazil) International Materials Congress, Rio de Janeiro, Brazil, 26-30 July 2010.

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Melich, M.E., "Oscillatory and Directional Emission Properties of Transition Metal Catalysts-Systems with Statistical Reliability," 15th International Conference on Condensed Matter Nuclear Science (ICCF-15), Rome, Italy, 5-9 October, 2009.

SEA 14 Briefings: NMAWC, PEO, LMW, NSWC Panama City, CNMOC, NFESC, EODTECHDIV, DHS S&T, DHS S&T Advisory Board, DHS PEO C-IED, HIS, CAN, NOIA USW Conference MIW Session, N85B I N8F-Navy Staff, USCG S&T, ONR C4I, QINETIQ, NOIA Industry Study-Significant Usage, Strategic Systems Program Office, SPA, INCOSE San Francisco Chapter, Northrop Grumman Sunnyvale BoD, Captain of the Port-Corpus Christi, COMSUBGRU 9, 2009 International Simulation Multi Conference-Istanbul, Turkey.

Williams, R.D., Lecture Sessions from the UW 2001 Lecture Series, presented to groups of scientists and engineers from NSWC Panama City, the Naval Mine and ASW Command, and the PEO LMW program offices.

CONFERENCES ORGANIZED

Ellis, W.G., Office of Naval Research Maritime Sensor Review Conference and provided the opening remarks, August 2009.

Ellis, W.G., Working with RADM Frank Drennan, Commander NMAWC, and with the leadership of NUWC, hosting an ASW Strategy Information Exchange at NPS on 20 April 2010.

Melich, M.E., 15th International Conference on Condensed Matter Nuclear Science (ICCF-15), Rome, Italy, 2009.

Williams, R.D., Office of Naval Research Sponsored CONTECH '09 War Game, conducted at NPS from 23-26 June 2009. (The results have been briefed to several Flag officers and their staffs, as well as presented at a variety of meetings. The War Game Reference Book, final presentation, and final report are available for review.)

Williams, R.D., 9th International Symposium on Technology and the Mine Problem (planned for 17-20 May 2010) was begun in 2009. The theme of the 2010 Symposium is "Technologies to Support Counter Mine Warfare, Advanced Underwater Weapons, and Expeditionary Warfare," with a detailed focus on unmanned systems' technologies, concepts, and applications.

CONFERENCES PARTICIPATED

Williams, R.D., Commander Third Fleet/Commander Mine and ASW Command Mine Warfare Improvement Program Meetings (2); NDIA Undersea Warfare Conference, California.

Williams, R.D., conducted presentations and participated in discussions about NPS activities with NECC, newly arriving personnel in OPNAV N85, Department of Homeland Security, NSWC Panama City, NSWC Port Hueneme, USMC Headquarters, and industry and sponsor groups.

Williams, R.D., East and West coast Amphibious and Mine Warfare Workshops, two meetings, 2009.

Williams, R.D., Navy League SEA Air Space Exposition; Surface Navy Association Annual Symposium, Expeditionary Combat Enterprise Board of Directors' meetings (2), Washington, D.C.

Williams, R.D., NDIA Mine Warfare Study, 2009.

Williams, R.D., NDIA Undersea Warfare Conference, Newport, Rhode Island.

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Williams, R.D., at the request of NSWC Port Hueneme, participated in several discussions about business opportunities and future Navy needs with a selection of their leadership, including a presentation to their senior-line managers and to about 100 of their senior persons, 2009.

Williams, R.D., ONR Joint Review of Unmanned Systems Technology Development, Mine Warfare Association Annual Conference, NDIA Expeditionary Warfare Conference, Florida.

Williams, R.D., Unmanned Technologies Table-Top Exercise 2009 (UTTX-09), Monterey, California, 2009.

CONTRIBUTIONS TO BOOKS

Marquis, F.D.S., “The Nanotechnology of Carbon Nanotube Nanofluids,” *Composites of Carbon Nanotubes and Applications*, Research Signpost, 2009.

Marquis, F.D.S., “The Nanotechnology of Carbon Nanotube Nanofluids,” *Functional Composites of Carbon Nanotubes and Applications*, Transworld Research Network, ISBN 978-81-7895-413-4, 2009.

BOOK

Lee, K.L., Gopalan, A.I., and Marquis, F.D.S., *Functional Composites of Carbon Nanotubes and Applications*, Transworld Research Network, ISBN 978-81-7895-413-4, 2009.

TEACHING MODULES

Marquis, F., Papoulias, F., and Yakimenko, O., “Fundamentals of Computers and Computing,” Instructional Modules for Systems Engineering Courses, 2009.

Marquis, F., Papoulias, F., and Yakimenko, O., “Fundamentals of Electrical Engineering,” Instructional Modules for Systems Engineering Courses, 2009.

**THE MOVES INSTITUTE
(MODELING, VIRTUAL
ENVIRONMENTS, AND
SIMULATION)**

**JOSEPH A. SULLIVAN
DIRECTOR**

MOVES INSTITUTE

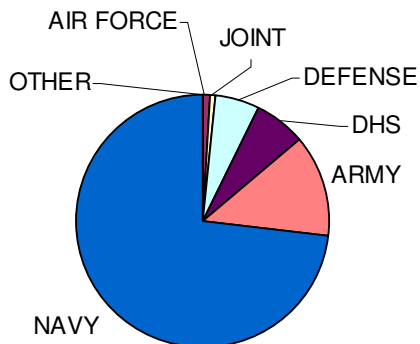
OVERVIEW:

Our mission is research, application, and education in the grand challenges of modeling, virtual environments, and simulation (MOVES).

The MOVES Institute operates independently and in collaboration with various U.S. Navy and defense modeling and simulation centers to: carry out basic and applied research; analyze continuing modeling, virtual environments, and simulation programs; create advanced prototypes; and develop real technologies and applications for the defense community.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the MOVES Institute is provided below:



Size of Program: \$3.5M

MOVES INSTITUTE

Joseph A. Sullivan
Director
CDR, USN, Military Faculty
831-656-7582
jasullivan@nps.edu

Jeffrey Appleget
Senior Lecturer
Department of
Operations Research
831-656-7674
jaappleget@nps.edu

Eric R. Bachmann
Lecturer
Department of
Computer Science
831-656-4066
bachmann@nps.edu

Wolfgang Baer
Research Associate Professor
831-656-2209
baer@nps.edu

Imre Balogh
Research Associate Professor
ilbalogh@nps.edu

William J. Becker
Research Assistant Professor
831-656-3963
wjbecker@nps.edu

Curtis Blais
Research Associate
831-656-2488
clblais@nps.edu

Gordon H. Bradley
Professor
831-656-2359
gbradley@nps.edu

Donald P. Brutzman
Associate Professor
of Applied Science
831-656-2149
brutzman@nps.edu

Arnold H. Buss
Research Assistant Professor
831-656-3259
abuss@nps.edu

Paul R. Chatelier
Research Associate Professor
831-656-2305
prchatel@nps.edu

Peter C. Chu
Professor
831-656-3688
pcchu@nps.edu

Anthony Ciavarelli
Professor
831-656-1073
aciavarelli@nps.edu

Christian J. Darken
Associate Professor
831-656-2095
cjdarken@nps.edu

Rudolph P. Darken
Professor
Department of
Computer Science
831-656-7588
darken@nps.edu

John S. Falby
Senior Lecturer
831-656-3390
falby@nps.edu

Donald P. Gaver
Distinguished Professor
831-656-2605
dgaver@nps.edu

John Hiles
Research Professor
831-656-2988
jehiles@nps.edu

Susan G. Hutchins
Research Associate Professor
831-656-3768
shutchins@nps.edu

Patricia A. Jacobs
Professor
831-656-2258
pjacobs@nps.edu

Quinn Kennedy
Lecturer
831-656-2618
mqkenned@nps.edu

Mathias N. Kolsch
Assistant Professor
831-656-3402
kolsch@nps.edu

Moshe Kress
Professor
831-656-2927
mkress@nps.edu

Theodore G. Lewis
Professor
831-656-2830
tlewis@nps.edu

Thomas W. Lucas
Associate Professor
831-656-3039
twlucas@nps.edu

Craig Martell
Associate Professor
831-656-2110
cmartell@nps.edu

Michael E. McCauley
Research Professor
831-656-2191
memccaul@nps.edu

Perry McDowell
Lecturer
Computer Science
831-656-7591
mcdowell@nps.edu

MOVES INSTITUTE

Nita Lewis Miller
Associate Professor
Department of Operations
Research and Department of
Information Sciences
831-656-2281
nlmiller@nps.edu

Eugene Paulo
Associate Professor
831-656-3452
eppaulo@nps.edu

Neil C. Rowe
Professor
831-656-2462
ncrowe@nps.edu

Amela Sadagic
Research Associate Professor
831-656-3819
asadagic@nps.edu

Paul J. Sanchez
Senior Lecturer
831-656-3053
pjsanche@nps.edu

Susan M. Sanchez
Professor
831-656-2780
ssanchez@nps.edu

Gurminder Singh
Professor
831-656-3041
gsingh@nps.edu

Ji Hyun Yang
National Research Council
Fellow
831-656-3004
jyan1@nps.edu

Xiaoping Yun
Professor
831-656-2629
yun@nps.edu

AN INTEROPERABILITY-STANDARDS COST-EFFECTIVENESS ANALYSIS TOOL

Wolfgang Baer, Research Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: There is an absence of quantitative metrics and measures that can help evaluate the cost effectiveness of implementing interoperability standards. In the absence of such metrics, standards are being implemented because “we all know they are good and necessary,” not because there is a clear guide as to when and how such implementations will save time and money. The goal of this research is twofold. First, to define a model that can be applied by decision makers in order to help them evaluate the cost and benefits of implementing specific interoperability standards, and second, to provide a tool for standards designers to help them optimize features and explain the cost benefits of adopting such standards in terms of tangible dollars and cents to the user community.

COMBATXXI: MCCDC BEHAVIOR DEVELOPMENT AND TECHNICAL SUPPORT

Imre Balogh, Research Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: U.S. Marine Corps Combat Development Command

OBJECTIVE: COMBATXXI is a high-resolution, analytic combat simulation that has been co-developed by MCCDC and TRAC-WSMR since 1998. The combined arms simulation represents individual entities (i.e., vehicles, aircraft, riflemen, etc.) at the tactical level of operations up to reinforced, battalion-sized units. The simulation is newly developed, with its first fully fielded release planned for October 2009. Modeling and analysis with preliminary versions of the model for the company-level FIRES study have been encouraging, although some documentation and desired functionality of interest to the Marine Corps has been lacking. COMBATXXI offers the capabilities of modeling amphibious operations and supporting detailed sensor-to-shooter analyses, including critical C4ISR links. However, this potential has yet to be realized due to lack of suitable behaviors and technical support within the MCCDC analytic environment. The MOVES Institute (Modeling, Virtual Environments, and Simulation) of the Naval Postgraduate School possesses the unique technical expertise to support and extend MCCDC’s analytic use of COMBATXXI.

MARINE CORPS SMALL ARMS AND MARKSMANSHIP TRAINING

William J. Becker, Research Faculty

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

OBJECTIVE: To conduct early investigation, risk mitigation, and prototyping on a new Marine Corps initiative in small arms and marksmanship training. While the Marine Corps currently has training capacity for these evolutions, there is a desire to move away from proprietary software and hardware solutions and move towards open platforms, open source, and open APIs so that the defense training community can bring its expertise and creativity to bear on these critical and enduring problems.

MODELING AND SIMULATION METADATA

Curtis L. Blais, Research Associate

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Space and Naval Warfare Systems Center-Charleston

OBJECTIVE: To provide technical consultation, research, and development in design and implementation of metadata schemes for Department of Defense modeling and simulation resources.

SOCIAL AND CULTURAL MODELING FOR NAVAL ANALYSES

Curtis L. Blais, Research Associate

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: Department of Defense Directive 3000.05, Military Support to Security, Stability, Transition, and Reconstruction Operations (SSTRO), requires the services to address these areas of warfare on equal footing with combat operations. Traditional modeling approaches that emphasized kinetic aspects of combat are ill-suited for the warfare decision-making needed today. New modeling approaches are required to help determine what non-kinetic assets and capabilities the Navy needs to employ now and in the future to provide the greatest benefit in the battle for “hearts and minds.” Over the past two years, OPNAV N81 has identified such modeling requirements in their annual planning. Students and faculty in the MOVES Institute (Modeling, Virtual Environments, and Simulation) have started to address some of these concerns, but additional effort is needed.

A DEMONSTRATION OF MODELING, ANALYSIS, AND VISUALIZATION CAPABILITIES SUPPORTING ANTI-TERRORISM HARBOR-DEFENSE EXERCISES

Donald P. Brutzman, Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Naval Installation Command

OBJECTIVE: To support CNIC in the design and development of a net-centric ashore/afloat Shore Force Center for Training and Exercises (SFCTE) that integrates joint training systems in a realistic Live, Virtual, Constructive (LVC) simulation environment using realistic scenarios aligned with the Navy continuous training environment. Various ashore and afloat exercises will be observed during both planning stages and operations. A variety of relevant software and hardware packages that might be used in the training center or at end-user commands will be reviewed, tested, and assessed. Supporting tasks will include: 1) performing studies and providing references that support the SFCTE initiative by leveraging Naval Postgraduate School resources, including consultation of modeling and simulation capabilities; 2) conducting market research and evaluation of technology developments and their potential to support SFTCE; 3) and providing subject matter expertise to CNIC staffs.

EXI, JAUS, AVCL, AND XML SUPPORT FOR AUTONOMOUS ROBOT CONTROL

Donald P. Brutzman, Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: U.S. Army Tank Automotive Research, Development, and Engineering Center

EXTENSIBLE 3D GRAPHICS AND COMPUTER-AIDED DESIGN

Donald P. Brutzman, Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Korea Advanced Institute of Science/Technology

OBJECTIVE: Research and a collaboration meeting and guest lecture on Extensible 3D(X3D) Graphics and computer aided design.

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THE MASSIVE MULTIPLAYER ONLINE WARGAME LEVERAGING THE INTERNET (MMOWGLI) FEASIBILITY STUDY

Donald P. Brutzman, Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Naval Undersea Warfare Center-Newport Division

OBJECTIVE: To show how existing and emerging standards-based technology capabilities can be combined to quickly create a MMOWGLI pilot project. The Naval Postgraduate School (NPS) will show the feasibility of using multiple, low-cost, open-standards, open-source capabilities in concert. Flexible tactical modeling and simulation will model wargame scenarios of interest by utilizing Viskit/Simkit discrete-event simulation (DES) behavior libraries. Web-accessible displays for team building and 2D analysis will adapt existing capabilities to a client-server architecture for maximum accessibility to Naval users.

Corresponding 3D visualization will use Extensible 3D (X3D) Graphics models in the Savage and SavageDefense (FOUO) model archives. Rapid scenario development will take advantage of ongoing military-officer modeling efforts using X3D-Edit and the SavageStudio authoring suite, and flexible relocation is possible by using easily updated X3D Earth terrain and bathymetry model archives. Network bridges to other simulations will be possible via NPS OpenDIS support for the IEEE Distributed Interactive Simulation (DIS) protocol, web servers, web services, and Extensible Messaging and Presence Protocol (XMPP) chat.

Multiple student theses will support this unique opportunity to produce a major new capability for team-play training.

MASTER'S THESIS RESEARCH, LCDR TARIQ RASHID: DEVELOPMENT OF A PERSISTENT VIRTUAL ENVIRONMENT INFRASTRUCTURE FOR USW TRAINING AND EXPERIMENTATION

Donald P. Brutzman, Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

OBJECTIVE: The thesis builds upon prior work exploring the requirements for persistent virtual environments for military applications. A demonstration of the requirements will measure the required system capabilities to support a persistent virtual environment for undersea warfare (USW) training and experimentation. Sun Microsystems Open-Source Massive Multiplayer Game Initiative, Project Darkstar, is being used to prototype a persistent virtual environment. As a specific application of this environment, interfaces will be developed to allow existing devices and models to interact with this environment. Specifically, the Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) tools and the NAVAIR TSD-developed SH-60B Mission Rehearsal Tactical Team Trainer (MRT3) are being used to conduct tests.

MISSION REHEARSAL AND POST-MISSION REPLAY SUPPORT FOR THE ATLANTIC UNDERSEA TEST AND EVALUATION CENTER

Donald P. Brutzman, Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Naval Undersea Warfare Center-Newport Division

OBJECTIVE: To provide mission rehearsal and post-mission replay support for the Atlantic Undersea Test and Evaluation Center (AUTEC) via the Naval Postgraduate School Autonomous Unmanned Vehicle Workbench (AUVW).

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THE UNDERSEA WARFARE EXTENSIBLE MARKUP LANGUAGE WORKING GROUP FOR AN ANTI-SUBMARINE WARFARE COMMUNITY-OF-INTEREST

Donald P. Brutzman, Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Naval Sea Systems Command

OBJECTIVE: Better data integration is needed for communications and information interchange among diverse, stovepiped anti-submarine warfare (ASW) tactical systems, both with each other and with complementary modeling and simulation systems. The Naval Postgraduate School and the Naval Undersea Warfare Center have extensive experience in the construction and integration of Extensible Markup Language languages for a variety of technical and tactical applications.

AMBIGUITY ATTRIBUTED TO DEGRADED SENSING

Arnold Buss, Research Assistant Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: The Sensor Ambiguity or Degraded Sensing Ambiguity (DSA) project seeks to characterize ambiguity attributed to degraded sensing conditions, single sensing modality, and finite sensing resources through modeling and simulation.

MODELING AND SIMULATION FOR CUSTOMS AND BORDER PATROL ANALYSIS

Arnold Buss, Research Assistant Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To create and analyze a simulation model to help determine the sensor mix that maximizes the probability of detecting.

MODELING AND SIMULATION OF GROUND SENSORS

Arnold Buss, Research Assistant Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To provide effective and efficient algorithms for modeling ground sensors for use in modeling and simulation efforts. The effectiveness and validity of the algorithms will be evaluated using experimental data, and the algorithms will be integrated into existing simulation models.

MODELING AND SIMULATION ISO THE NEW STRATEGY

Arnold Buss, Research Assistant Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Joint Warfare Analysis Center

OBJECTIVE: To assist researchers at the Joint Warfare Analysis Center in defining research problems and planning a research agenda for their New Strategy (TNS) initiative. This research is intended to facilitate preliminary research (research problem identification and definition), travel, coordination, and planning activities. This project includes two meetings to be held in Monterey, which requires travel for one of the investigators who normally works remotely from the MOVES Institute (Modeling, Virtual Environments, and Simulation). This is a preliminary project and is expected to result in a multi-year follow-on project at the MOVES Institute.

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WORLD CLASS MODELING (WMC)-09CA-08: A FORCE RESPONSE TOOL

Arnold Buss, Research Assistant Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Chief of Naval Operations

OBJECTIVE: To design a tool that is capable of quick turn around analysis of different Navy force structures. In addition to being capable of examining the effects of different force structures, the tool will be able to examine the effects of forward presence, maintenance, and training schedules on the overall responsiveness of the force.

ADVANCED HUMAN-SYSTEMS INITIATIVES AT THE NAVAL POSTGRADUATE SCHOOL'S MOVES INSTITUTE

Paul Chatelier, Research Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

OBJECTIVE: To provide research and development program support to the Office of Naval Research in the HS(I) domain areas, including research and analysis and S&T assessments. Discussions with Code 341 have indicated that they would also like the Naval Postgraduate School (NPS) to possibly play a role in identifying new, advanced human-systems-assessment initiatives that might have an impact on their Synthetic Environment for Assessment (SEA) Program. Of special interest is investigating what joint modeling and simulation education and research might be able to provide for SEA. This includes determining how NPS modeling and simulation (M&S) current and proposed efforts can be provided to the Fleet via networking, as well as how M&S technologies might better integrate and improve Navy inter-laboratory human-systems-assessment capabilities.

MEDICAL SIMULATION AND TRAINING TECHNOLOGY

Paul Chatelier, Research Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Telemedicine and Advanced Technology Research Center

OBJECTIVE: To provide the expertise necessary to perform simulation projects and technology investment strategy.

DEVELOP, TEST, AND EVALUATE PERFORMANCE AND TRAINING EFFECTIVENESS EVALUATION METHODS: MARKSMANSHIP TRAINING AS A TESTBED APPLICATION

Anthony P. Ciavarelli, Research Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: The Navy and Marine Corps are rapidly developing and fielding advanced virtual environment (VE) training systems which purport to enhance, and maybe replace, traditional live-training exercises. Questions remain, however, concerning whether or not the goals of enhancing or replacing field training are valid assumptions. The proposed tasking represents a follow on to FY08 efforts to develop and test methods for assessing human performance and training effectiveness in VE training systems. Research on the use of human-performance measurement methods and training-system effectiveness evaluation are needed to fill important gaps in understanding how to best demonstrate that current, advanced, virtual-environment training systems are performing as intended — to establish and maintain necessary skills and acceptable proficiency levels of the war-fighter. The main objective of this research is to finalize the ongoing efforts to define quantitative and qualitative methods for evaluating the training benefit and effectiveness of virtual environment trainers and simulators. Marksmanship training, at all levels (basic and advanced), serves as the initial testbed for the development and validation of generalizable measurement

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and assessment methods. Results of this study will be useful in assisting simulation trainers and acquisition managers regarding the design, use, and utility of VE training systems.

ADVANCED DISTRIBUTED-LEARNING INITIATIVES AT THE NAVAL POSTGRADUATE SCHOOL

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Defense Human Resources Activity

OBJECTIVE: To assist in the exploration and development of distributed learning initiatives that support the Naval Postgraduate School (NPS) Strategic Plan. In short, harnessing the current and future potential of distributed learning technologies is critical to the success of NPS as a university. The Advanced Distributed Learning program (<http://www.adlnet.gov>) has been a catalyst for the development of current interoperable technologies for enhancing the sharing of distributed learning resources.

A DISRUPTIVE COMMERCIAL TECHNOLOGY ASSESSMENT: ELECTRIC TRANSPORTATION, BATTERY TECHNOLOGY, AND LOCAL POWER GRIDS

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

OBJECTIVE: To conduct a technology assessment of battery technology, electric transportation, and the operation of a power grid with a perspective towards military operations in a deployed setting. How might the technologies being developed commercially in the U.S. be used to alter transportation and power requirements in forward-deployed environments in the future?

EDUCATIONAL DOMINANCE PROGRAM SUPPORT

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: To provide programmatic and advisory support to the Program Manager (PM) for the Educational Dominance DARPA program; to support the PM directly and as performers in assisting in experimental design and logistics for experiments.

HUMAN, SOCIAL, CULTURAL, AND BEHAVIORAL PROGRAM

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of the Deputy Under Secretary of Defense

OBJECTIVE: To provide programmatic and advisory support to the Human, Social, Cultural, and Behavioral (HSCB) program. The principal investigator (PI) will lead Naval Postgraduate School HSCB workshops and lead the technical community in connection with OSD requirements. The PI will conduct technical assessments as required and will evaluate potential HSCB performers and teams.

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HUMAN, SOCIAL, CULTURAL, AND BEHAVIORAL PROGRAM SUPPORT

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of the Deputy Under Secretary of Defense

OBJECTIVE: To provide advisory support to the Human, Social, Cultural, and Behavioral (HSCB) Program. The principal investigator (PI) will conduct the analyses and assessments necessary to assist the HSCB management in ensuring that HSCB research directions and analytic architectures are theoretically and technically appropriate.

INTEGRATED SOLDIER SITUATIONAL AWARENESS/SEARCH AND TARGET ACQUISITION MODELING

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To design an experiment to investigate the relationship between SA and STA, particularly the preparation of an experimental stimulus in the form of a 3D virtual environment. This environment needs to be adjustable along various dimensions to be determined by the project team so as to ensure proper control of the experiment. The environment consists of a program that can run on standard (upper end) computers, possibly with multiple, simultaneous monitors and supported by eye tracking. This project also includes background research, support for data analysis, and conceptual algorithm development.

INTEROPERABILITY FOR MODULAR APPLICATIONS USING A REAL-TIME SOA

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: To explore how “interoperability” in modeling and simulation changes when we progress from discovery of metadata across applications to completely modular applications with interchangeable parts. NMSO refers to this as “Phase Three” in the evolution of interoperability.

MARINE CORPS SMALL ARMS AND MARKSMANSHIP TRAINING

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

OBJECTIVE: To conduct early investigation, risk mitigation, and prototyping on a new Marine Corps initiative in small arms and marksmanship training. While the Marine Corps currently has training capacity for these evolutions, there is a desire to move away from proprietary software and hardware solutions and towards open platforms, open source, and open APIS so that the defense training community can bring its expertise and creativity to bear on these critical and enduring problems.

REPRESENTING AMBIGUITY AND DECISION-MAKING WITHIN BATTLEFIELD INFORMATION FLOWS

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To leverage previous research to examine the feedback effects of both ambiguity and ambiguity-coping strategies on cyclic decision-making processes and battlefield information flows. It will expand upon a previously developed model for battle damage assessment (BDA) and a Blue Force

information model of threat forces for current and future forces that realistically accounts for inaccurate/uncertain identification/classification/affiliation of acquired entities and accounts for imperfect association of this information.

RUN-TIME COURSE-OF-ACTION MODIFICATION FOR SIMULATED ENTITIES

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: Current military simulations do not have adequate support for allowing simulated forces to respond to new information that becomes available during the course of a run. In real operations, it is very normal for very significant information, such as details of terrain or actual positions of enemy forces, to be acquired only during the actual operation. Real soldiers adapt their plans to such circumstances; simulated ones should too. The goal of the proposed work is to significantly improve the state of the art by providing means for simulated forces to dynamically plan routes and otherwise adjust their planned course of action during the course of a simulation run.

TECHNOLOGY DEVELOPMENT AGENT SUPPORT FOR NEW-IT AND BASE-IT

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

OBJECTIVE: Training and assessment for an expeditionary-warfare technology development agent (TDA) in support of current, capable, manpower projects and principal investigators.

TERRAIN ANALYSIS TOOL BACKGROUND RESEARCH

Rudolph P. Darken, Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: A literature review and preliminary research and development to create an offline tool to augment traditional Combat XXI terrains with the node and arc representation necessary for online path finding will be performed. The primary goal is to provide a detailed description of viable courses of action for developing a usable automated route.

THE INTEGRATION OF ROBOTIC TECHNOLOGY/COMPUTER GRAPHICS/DIGITAL HOLOGRAPHY TO MODERNIZE THE EXPEDITIONARY WARFARE DEMONSTRATOR

Christian R. Fitzpatrick-Major, United States Marine Corps

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Space and Naval Warfare Systems Center-Pacific

OBJECTIVE: The most unique aspect of this thesis is the use of modeling and virtual environment technology to provide training in joint maritime operations. There is no question that the Navy and the Marine Corps set the standard for joint operations across all services. The Expeditionary Warfare Demonstrator (EWD) could be the maritime operations classroom of the future and could provide instruction and demonstrate the intricate command and control requirements of a successful amphibious assault. The current EWD technology, developed in the early 1950s, lacks credibility with young Marines and Sailors. This investigation of applicable technologies will focus on changing to adapt to their learning skills.

MOVES INSTITUTE

GREATER AUTONOMY FOR USVS IN RIVERINE ENVIRONMENTS

Mathias N. Kolsch, Assistant Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

SUMMARY: Funds are provided for Mr. Horner to collaborate with Stilwell (Virginia Tech) to develop the capability for an unmanned surface vessel to operate quickly and autonomously in unknown riverine environments. The principal investigators will develop autonomous navigation algorithms and technologies to identify obstacles, both moving and non-moving, and then optimally plan and re-plan a course in real-time. Developments will lead to a field demonstration at the end of year one.

MOVES CURRICULUM IMPROVEMENTS

Mathias N. Kolsch, Assistant Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: To improve the MOVES (Modeling, Virtual Environments, and Simulation) curriculum with a multi-pronged approach, keeping MOVES graduates the best-educated and providing Department of Defense modeling and simulation specialists with highly relevant expertise for their next jobs.

PANORAMIC AUGMENTED REALITY FOR PERSISTENT INFORMATION IN COUNTERINSURGENCY

Mathias N. Kolsch, Assistant Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Center for Army Analysis

OBJECTIVE: This research is for an inertia measurement sensor and global positioning system (IMS/GPS) and a software package to tender geospatially registered information. This will add additional capabilities to the PARPICE Project, namely, spatio-temporal registration of video with LiDAR data. LiDAR is a light detection and ranging sensor, establishing a three-dimensional view of the world.

The focus of the PARPICE research and prototype system development is to integrate spatially related data into a synthetic view of the outside environment for use by vehicle commanders, via a visually augmented, indirect-vision system. Street names, building information, and intelligence data will be used in conjunction with video from vehicle-mounted cameras. Terrain-associated-knowledge hence persists in-place in the environment, rather than being verbally relayed, stored in text documents or on paper maps, or being lost entirely. Crucial information – unobtrusively displayed at the right moment and place – allows a vehicle crew to better understand their operational environment, to be aware of threats that may be present, and ultimately, to improve situational awareness and crew safety.

SOCIAL NETWORK REPRESENTATION AND ANALYSIS

Steve Lieberman, SMART Scholar

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: TRADOC Analysis Center-Monterey

OBJECTIVE: To address the use of social network models and simulations in irregular warfare operations. Deliverables include phased technical reports on theories and methods underlying the quantification of relationships, influence, and persuasion using social network models, and an implementation plan for social network models.

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CENTRIFUGE MOTION BASE WORKSHOP

Michael McCauley, Research Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Naval Air Systems Command

OBJECTIVE: To discuss the benefits and potential drawbacks of implementing this type of motion base in training simulators for fighter pilots. These technical issues are part of a larger context of simulator fidelity and training effectiveness that is central to the MOVES Institute (Modeling, Virtual Environments, and Simulation).

F/A-18C-F DEPLOYABLE MISSION READINESS TRAINER TRAINING SITUATION ANALYSIS

Michael McCauley, Research Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Naval Air Systems Command

OBJECTIVE: Deployable Mission Readiness Trainer (DMRT) gap analysis and government, off-the-shelf software (GOTS) systems integration assessment.

THE FUTURE OF FLEET TRAINING SYSTEMS INTEGRATION

Michael McCauley, Research Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: To improve the understanding of the current application of simulation for training within the Fleet; and to help identify and address current and future training integration issues. Information from this research effort will be used to improve the curriculum content, research agenda, and simulation infrastructure within the MOVES Institute (Modeling, Virtual Environments, and Simulation). Critical issues affecting training system integration will be identified and addressed. Results of this effort will be used to refine the longer-term research strategy and to target opportunities to improve the training system.

S1000D ANALYSIS

Michael McCauley, Research Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of the Under Secretary of Defense

OBJECTIVE: To identify the perceived benefits and drawbacks to implementing S1000D. Current and potential users of this guideline will be interviewed to determine the basis for decisions to adopt or reject the S1000D standard. A survey questionnaire will be developed and administered, and the resulting data will be analyzed. Results of all aspects of the analysis will be provided in a final report.

STRESS TRAINING FOR ENHANCING PERFORMANCE IN A STRESSFUL FLIGHT ENVIRONMENT

Michael McCauley, Research Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Air Education and Training Command

OBJECTIVE: To investigate the effects of stress training on stressful flight operations in order to mitigate the human factors preconditions to aircraft accidents and to improve initial flight-training effectiveness. In addition, stress-training implementation strategies will be investigated.

CREATING A GAME-BASED PORT-PROTECTION TRAINER

Perry McDowell, Research Associate

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Federal Law Enforcement Training Center

OBJECTIVE: To create a trainer for use in the Federal Law Enforcement Training Center's Maritime Division course *Seaport Security Antiterrorism Training Program*. The game will be used to teach and evaluate students in the Seaport Facility Inspection portion of the class. The Seaport Facility Inspection Program teaches students how to perform inspections of port facilities and ensure that they are complying with required laws and regulations regarding protection from attack.

CREATING A PROOF-OF-CONCEPT/DEMONSTRATION-OF-GAME-BASED MARITIME EMERGENCY TRAINER

Perry McDowell, Research Associate

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Naval Air Warfare Center Aircraft Division

OBJECTIVE: To create a proof-of-concept of a game-based trainer to train non-co-located personnel how to work together in responding to a maritime emergency. The goal of this trainer is to both train personnel and create socialization aspects so that the personnel are familiar with working with each other prior to an incident.

DEVELOPING A GAME FOR MASINT INSTRUCTION

Perry McDowell, Research Associate

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Air Education and Training Command

OBJECTIVE: To develop a measureable, gaming-based simulation with adaptive learning capability. The simulation will be built using the existing open-source Delta 3D gaming engine and embedded within the Blackboard Learning Management System (LMS) as a learning tool for intelligence analysts, mission planners, and battlefield commanders.

SUMMARY: The results include: proof-of-concept that learning system and training (through gaming) system interoperability truly provide higher degrees of user interactivity, and fidelity and immersion in a contextual and practical learning environment exist. The results also lead to the conversion of all Air Force Institute of Technology MASINT courses into online delivery for eventual availability to Department of Defense and intelligence analysts.

EXAMINING THE DEPARTMENT OF DEFENSE'S ROLE IN OPEN SOURCE SOFTWARE

Perry McDowell, Research Associate

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: To explore how the Department of Defense can utilize funding, acquisition procedures, and technology to improve its employment of open source software.

INVESTIGATIONS INTO USING GAME ENGINES AS THE BASIS OF DEFENSE-BASED GAME-BASED TRAINING AND ANALYSIS

Perry McDowell, Research Associate

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Lockheed Martin Simulation, Training and Support

SUMMARY: Games-based systems are becoming vital to many areas within the Department of Defense, especially training and analysis. Lockheed Martin Simulation, Training, and Support (LMSTS) currently shares an interest corresponding with building systems using game-based engines. Working together, the Naval Postgraduate School and LMSTS will investigate how game-based systems can be used for training and analysis, including what modifications may be needed and examining different business models and resource requirements.

PROVIDE DELTA SUPPORT FOR STTC-RDECOM

Perry McDowell, Research Associate

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Research Development and Engineering Command

OBJECTIVE: To provide support in using and modifying the Delta3D game engine to meet the needs of the Simulation and Technology Training Center of the Army's Research, Development, and Engineering Command.

AN EVALUATION OF THE EFFECTIVENESS OF SURFACE AND SUB-SURFACE SIMULATORS TO TRAIN NON-TECHNICAL SKILLS

Paul O'Connor, Deputy Director

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: To identify how simulators are being used to train personnel in the surface and sub-surface Navy, with a particularly focus on non-technical skills. Non-technical skills are cognitive, social, and personal resource skills that complement technical skills and contribute to safe and effective task performance (e.g., decision making, situation awareness, communication, managing stress, etc.).

This research will allow MOVES Institute faculty to better understand how these communities are using simulators for training, and incorporate this knowledge into their lectures and research agendas. Further, an examination of how simulators are employed to train non-technical skills will be carried out in the context of how these skills are being trained in other high-risk organizations.

BEHAVIOR ANALYSIS AND SYNTHESIS FOR INTELLIGENT TRAINING: BASE-IT

Amela Sadagic, Research Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

OBJECTIVE: To develop a state-of-the-art intelligent-training system for pre-/in-/post- evaluation using behavior analysis, review, and behavior synthesis; and to develop a set of training approaches to support a wide range of training and operational needs in preparing for and conducting the training in MOUT facilities.

MOVES INSTITUTE

3D DISPLAY AND CAPTURE OF HUMANS FOR LIVE-VIRTUAL TRAINING

Amela Sadagic, Research Associate Professor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of Naval Research

OBJECTIVE: To research, develop, and evaluate work in 3D display and sensing, initially examined at mixed/augmented reality-based live-virtual training, but with significant potential for broader impact.

ADVANCED DISTRIBUTED-LEARNING INITIATIVES AT THE NAVAL POSTGRADUATE SCHOOL

CDR Joseph A. Sullivan, USN, Military Instructor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To assist in the exploration and development of distributed learning (DL) initiatives that support the Naval Postgraduate School (NPS) strategic plan. In short, harnessing the current and future potential of distributed learning technologies is critical to the success of NPS as a university. The Advanced Distributed Learning (ADL) Program (<http://www.adlnet.gov>) has been a catalyst for the development of current interoperable technologies for enhancing the sharing of distributed learning resources.

EDUCATIONAL DOMINANCE PROGRAM SUPPORT

CDR Joseph A. Sullivan, USN, Military Instructor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: To provide programmatic and advisory support to the Program Manager (PM) for the Educational Dominance DARPA Program; to support the PM directly and assist in experimental design and logistics for experiment execution.

MEETING AND INTERNATIONAL HOSPITALITY SUPPORT: HOSTING A SUMMIT TO EXPLORE ADL INITIATIVES AT THE NAVAL POSTGRADUATE SCHOOL

CDR Joseph A. Sullivan, USN, Military Instructor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Advanced Technology Institute

OBJECTIVE: ADL is expanding beyond direct learning activities to broader life-cycle support for learning, training, and performance requirements in the acquisition and work environment. ADL, FMV, ONR, and the Naval Postgraduate School (NPS) will be discussing these ideas and the impact on NPS curricula, research and development, emerging technologies, the use of standards, human systems integration and distance support. To maximize efficient use of time and opportunities to grow professional relationships in this small but growing space, NPS has been asked to establish a meeting environment and hospitality occasions conducive to the meeting objectives.

MOVES INSTITUTE ADMINISTRATIVE AND INFRASTRUCTURE SUPPORT

CDR Joseph A. Sullivan, USN, Military Instructor

MOVES Institute (Modeling, Virtual Environments, and Simulation)

Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: To support the technical and administrative efforts required to sustain a superior education and research program in defense modeling and simulation. The main effort involves research to ensure the MOVES Institute (Modeling, Virtual Environments, and Simulation) core competencies and research

MOVES INSTITUTE

agenda are aligned with the needs of the Navy Modeling and Simulation Office, the demand for next-generation modeling and simulation tools, emerging technology, and end-user requirements.

MOVES INSTITUTE AND CURRICULUM SUPPORT TASK 00
CDR Joseph A. Sullivan, USN, Military Instructor
MOVES Institute (Modeling, Virtual Environments, and Simulation)
Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: The Naval Postgraduate School, in conjunction with RDA Cheng (Navy Modeling and Simulation Office (NMSO)), has established a degree program, the Modeling, Virtual Environments, and Simulation (MOVES) curriculum, and a research institute, the MOVES Institute. The degree program generates officers capable of filling 6202P-coded billets upon graduation. The program is roughly half computer science and half operations analysis. The goal is to produce officers with an understanding of modern modeling, virtual environments, and simulation. This research will provide faculty, student, and staff support on issues of interest to NMSO community stakeholders (analysis, acquisition, training, and Marine Corps) and to couple student theses to NMSO objectives.

PORTABLE VIRTUAL ENVIRONMENTS FOR TRAINING IN TRANSIT
Xiaoping Yun, Associate Professor
MOVES Institute (Modeling, Virtual Environments, and Simulation)
Sponsor: Navy Modeling and Simulation Office

OBJECTIVE: Immersive training in virtual environments can be used for mission rehearsal of marines while in transit and for training of shipboard personnel in tasks such as fire fighting. However, synthetic training systems have been plagued by the need for elaborate and expensive infrastructures designed to track user movement. These infrastructures require extensive setup and calibration and are thus not easily moved. Often the systems require dedicated spaces, making them unavailable for other purposes. The objective is to develop a self-contained, immersive, synthetic training system that would be portable and relatively inexpensive.

**THE MOVES INSTITUTE
(MODELING, VIRTUAL
ENVIRONMENTS, AND
SIMULATION)**

**2009
Faculty Publications
and Presentations**

CONFERENCE PUBLICATIONS

Blais, C., Dodds, R., Pearman, J., and Baez, F., "Rapid Scenario Generation for Multiple Simulations: An Application of the Military Scenario Definition Language (MSDL)," *Paper 09S-SIW-003, Proceedings of the Spring Simulation Interoperability Workshop*, Simulation Interoperability Standards Organization, San Diego, California, March 2009.

Blais, C., Abbott, J., Diallo, S., Levine, S., Gustavsson, P.M., Nero, E., and Turnitsa, C., "Coalition Battle Management Language (C-BML) Phase 1 Specification Development: An Update to the M&S Community," *Paper 09S-SIW-002, Proceedings of the Spring Simulation Interoperability Workshop*, Simulation Interoperability Standards Organization, San Diego, California, March 2009.

Blais, C., Brown, D., Diallo, S., Heffner, K., Levine, S., Singapogu, S., et al., "Coalition Battle Management Language (C-BML) Phase 1 Specification Development: An Update to the M&S Community," *Paper 09F-SIW-001, Proceedings of the Fall Simulation Interoperability Workshop*, Simulation Interoperability Standards Organization, Orlando, Florida, September 2009.

Gustavson, P., Nikolai, A., Scrudder, R., Blais, C., and Daehler-Wilking, R., "Discovery and Reuse of Modeling and Simulation Assets," *Paper 09S-SIW-076, Proceedings of the Spring Simulation Interoperability Workshop*, Simulation Interoperability Standards Organization, San Diego, March 2009.

Johnson, J. and Blais, C., "Software Hardware Asset Reuse Enterprise (SHARE) Repository Framework," *Proceedings of the 6th Annual Acquisition Research Symposium*, Monterey, California, May 2009.

Leong, H.W., Brutzman, D., McGregor, D., and Blais, C., "Web Services Integration on the Fly," *Proceedings of the Spring Simulation Multi-Conference*, San Diego, California, March 2009.

Sadagic, A., "Virtual Training Simulations and Game-Based Systems: Large-Scale Adoption Issues," *Military Modeling and Simulation Symposium, SpringSim Conference*, San Diego, California, March 2009, (invited I/ITSEC tutorial).

Sadagic, A., Welch, G., Basu, C., Darken, C., Kumar, R., Fuchs, H., et al., "New Generation of Instrumented Ranges: Enabling Automated Performance Analysis," *Proceedings of 2009 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC-2009)*, Orlando, Florida, 2009.

Tolk, A., Blais, C.L., Diallo, S.Y., and Turnitsa, C., "Conceptual Requirements for Command and Control Languages," *Paper 09F-SIW-075, Proceedings of the Fall Simulation Interoperability Workshop*, Simulation Interoperability Standards Organization, Orlando, September 2009.

Weekley, J. and Brutzman, D., "3D Technologies for the World Wide Web," *Proceedings of the 14th International Conference on 3D Web Technology*, pp. 71-77, ISBN:978-1-60558-432-4, Darmstadt, Germany, 2009 (<http://portal.acm.org/citation.cfm?id=1559776>).

Whittington, E. and Blais, C., "Extending Capabilities of the Military Scenario Definition Language (MSDL) for Nontraditional Warfare Scenarios," *Paper 09S-SIW-001, Proceedings of the Spring Simulation Interoperability Workshop*, Simulation Interoperability Standards Organization, San Diego, California, March 2009.

**CENTER
FOR INTERDISCIPLINARY
REMOTELY PILOTED
AIRCRAFT STUDIES**

**ROBERT T. BLUTH
DIRECTOR**

OVERVIEW:

The Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) is a research center at the Naval Postgraduate School (NPS). The Office of Naval Research established CIRPAS in the spring of 1996. CIRPAS provides measurements from an array of airborne and ground-based meteorological, aerosol, and cloud particle sensors, radiation and remote sensors to the scientific community. The data are reduced at the facility and provided to the user groups as coherent datasets. The measurements are supported by a ground-based calibration facility. CIRPAS conducts payload integration, reviews flight safety, and provides logistical planning and support as a part of its research and test projects around the world. The Center operates a variety of manned aircraft and unmanned aerial vehicles (UAV). CIRPAS is also a National Research Facility of UNOLS.

The facility provides unique flight operation and scientific measurement services by:

- Providing access to manned aircraft, UAVs, support equipment, and scientific instruments, thus sparing users the cost of ownership and guaranteeing equal access by all interested parties on a first-come first-served basis.
- Instrumenting and operating aircraft to meet the requirements of a variety of individual research and test programs.
- Developing new instrumentation to meet increasing challenges for improvements in meteorological and oceanographic measurements.
- Calibrating, maintaining, and operating the facility's airborne instruments in accordance with individual mission specifications.
- Integrating auxiliary payloads as required and handling flight safety and logistics tasks, allowing the user to concentrate on his specific mission goals.

The facility has unique UAV flight services, including:

- An available and centralized repository of diverse UAV assets to meet the needs of individual programs.
- Access to the UAVs and support equipment on a "lease" basis so the user is spared the cost of ownership.
- Turnkey UAV operations, including payload integration, flight safety, and logistics support.
- Low-cost services using shared assets.

CIRPAS provides cost-effective flight services, which benefits a broad spectrum of research. CIRPAS operates out of two facilities. The primary site is located near the NPS campus at the Marina Municipal Airport. This facility includes a 30,000 square foot hangar and maintenance and administrative spaces for CIRPAS staff. These include a fully outfitted machine shop, an electronics room, and a calibration lab for the upkeep of scientific instrumentation. The second site is at McMillan Airfield, Camp Roberts, California, 90 miles south of the Marina facility. The Camp Roberts site provides the Center with a base of operations for both manned and unmanned aerial-vehicle flight activities.

The California Institute of Technology supports CIRPAS as the prime contractor. It is also partners with NPS in providing the latest instrumentation for atmospheric research.

RESEARCH THRUSTS:

- Atmospheric and Oceanographic Research
- Fleet and USJFCOM Exercises
- Support for CONOPS Development
- Payload Test and Evaluation
- UAV Experimentation with Operational Forces supported by Analysis Provided by NPS Departments and Institutes

THE CIRPAS AIRCRAFT

UV-18A “Twin Otter”: The CIRPAS UV-18A “Twin Otter” has two primary missions. The vehicle’s large, useful load makes it ideal for carrying instrumentation for atmospheric/oceanographic research. The twin turboprop Short Takeoff and Landing (STOL) aircraft can cruise at very low speeds for long durations. The aircraft has a maximum takeoff weight of 13,500 pounds.

Characteristics of the CIRPAS Twin Otter include:

- Maximum endurance of 5 hrs. (extended further during ferry operations)
- Maximum altitude of 25kft
- 70-160 KIAS operational speed range
- 200 amp of payload power (DC and AC combined)
- Wing span of 65 ft.
- GTOW of 13,500 lbs. (~6000 lbs. useful)

Pelican: The Pelican is a highly-modified Cessna 337 Skymaster originally developed by the Office of Naval Research for low-altitude, long-endurance, atmospheric and oceanographic sampling. With additional support from NASA’s ERAST Program, the air vehicle has been configured to operate as a UAV surrogate. In the UAV surrogate role, Pelican provides a low-risk, low-cost, test and evaluation platform by avoiding the airspace restrictions and other complications associated with unmanned aircraft operations. CIRPAS’ second Pelican air vehicle is a converted Cessna O2-A. It is operated without the Predator avionics equipment and is available for use in support of a variety of generic payload demonstrations.

Characteristics of the Pelican include:

- Maximum endurance of 15 hrs.
- Maximum altitude of 15kft
- Cruise speed of 90 KIAS
- Nose payload bay capacity of 330 lbs.
- Wing hardpoints and cabin space for additional payloads
- 1.2 kW of payload power
- Wing span of 42 ft.
- GTOW of 4600 lbs.

Altus ST UAV: The Altus Single Turbo (ST) UAV was developed by General Atomics ASI to support the high-altitude atmospheric-monitoring requirements of NASA’s Environmental Research Aircraft and Sensor Technology Program. The Altus TM UAV is based on the proven Predator TM and GNAT TM line of unmanned aircraft. The Department of Energy’s Sandia National Labs funded the fabrication of a single-stage turbocharged Altus TM UAV to support the Atmospheric Radiation Measurement (ARM) Science Campaign. As a result of a cooperative agreement with the DoE, CIRPAS provides the vehicle’s services during the remainder of the year to other users.

Characteristics of the Altus ST include:

- Maximum endurance of 30 hrs.
- Maximum altitude of 45kft
- Cruise speed of 70 KIAS
- Nose payload bay capacity of 330 lbs.
- 1.2 kW of payload power
- Wing span of 55 ft.
- GTOW of 2100 lbs.

Predator UAV: CIRPAS maintains and operates the U.S. Navy's only two Predator UAVs. One air vehicle is configured with the EO/IR, SAR, and Ku-band SATCOM payloads; the other aircraft has the EO/IR payload only. The Predators and payloads were provided to CIRPAS as a result of the Center's Tactical Control System (TCS) developmental and operational test support. The air vehicles and payloads are available for other RDT&E or CONOPS development activities on a not-to-interfere basis with the TCS Program Office objectives.

Characteristics of the Predator UAV include:

- Maximum endurance of 36 hrs.
- Maximum altitude of 25kft
- Cruise speed of 70 KIAS
- Nose payload bay capacity of 450 lbs., wing hardpoints
- 1.8 kW of payload power
- Wing span of 48 ft.
- GTOW of 2250 lbs.

GNAT-750 UAV: The GNAT-750 UAV was developed by General Atomics ASI to support unmanned, medium altitude, endurance surveillance and other sampling requirements. The GNAT-750 is the predecessor to the Predator UAV.

Characteristics of the GNAT-750 UAV include:

- Maximum endurance of 30 hrs.
- Maximum altitude of 18kft
- Cruise speed of 70 KIAS
- Nose payload bay capacity of 125 lbs.
- 1.2 kW of payload power
- Wing span of 35 ft.
- GTOW of 1450 lbs.

Ground-Control Station: The General Atomics ASI Ground-Control Station (GCS) provides aircraft control functions for the CIRPAS-operated UAVs. The GCS has redundant pilot/payload operating stations and is housed in a rugged, 18-foot-long, wheeled container. CIRPAS currently owns two GCSs and associated ground data terminals capable of operating Predator/Altus/GNAT-750/Pelican air vehicles. GCS #1 includes one UHF and dual VHF radios for communication to other aircraft, range, or ATC personnel. Additional radios provide direct communication between flight crew and other personnel if a requirement exists. GCS #1 also has a video closed-captioning system to overlay aircraft and target position data on imagery before transmission to user.

Atmospheric/Oceanographic Aircraft Payloads: CIRPAS can provide use of a wide variety of atmospheric and oceanographic sensors to the research community. The CIRPAS sensor suite includes off-the-shelf instrumentation, as well as one-of-a-kind, custom-built packages. CIRPAS possesses a variety of scientific instruments and instrument suites. The basic meteorological and GPS suite consists of a Rosemount temperature probe, an Edgetech chilled-mirror, a dew-point sensor, a Rosemount flow-angle probe with static ports, Vaisala temperature and dewpoint sensors, a Novatel GPS receiver with a ground survey station for differential correction, a TANS Vector GPS attitude system, a CMidget-II INS-GPS system, an IRGA humidity and carbon-dioxide sensor, and an Aerodyne fast absolute humidity sensor. The CIRPAS aerosol instrumentation suite consists of a TSI three-color nephelometer, a radiance soot photometer, a TSI ultrafine-particle counter, and a TSI condensation-nuclei counter. The CIRPAS cloud and particle instrumentation suite consists of an FSSP-100, a PCASP-100X (both with upgraded electronics), a CAPS scatter and occultation probes, DMT 2D-P and 2D-PP probes, and a TSI aerodynamic particle spectrometer.

RESEARCH FACILITIES:

Marina Facility

- 30,000 sq ft. maintenance hangar
- 3000 ft. runway - manned operations only
- Naval Reserve Unit
- Office space, flight operations

Maintenance Facility

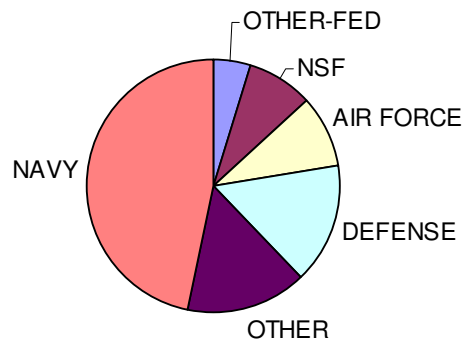
- Payload development and integration
- Logistics planning and support to research and test projects

Camp Roberts Facility

- Friendly airspace for testing and training (R2503)
- Military ground maneuvers (equipment, personnel)
- 3500 x 60 ft. runway
- 2000 sq ft. hangar
- Shared utilization of NRL temporary office space

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Center for Interdisciplinary Remotely Piloted Aircraft Studies is provided below:



Size of Program: \$2.5M

Robert T. Bluth
Research Associate and Director
831-384-2776
rtbluth@nps.edu

Haflidi H. Jonsson
Research Assistant Professor
831-384-2776
hjonsson@nps.edu

Roy Woods
Research Assistant
831-384-2776
rkwoods@nps.edu

THE AEROMECH ENGINEERING FLIGHT TEST

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: AeroMech Engineering, Inc.

OBJECTIVE: To provide pre-flight coordination, flight coordination, range management, flight safety and facility management of AeroMech, Inc. activities, while conducting flight testing of the unmanned, aerial vehicle at the CIRPAS facility and ensuring compliance with all CIRPAS and Caltech policies and procedures.

AEROVIRONMENT SUAV FLIGHT-RANGE ACTIVITIES

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: AeroVironment, Inc.

SUMMARY: AeroVironment flight testing is currently scheduled for 15 June to 31 May 2010, however, this is subject to change. Work will begin as soon as funding is received and administrative tasks may continue until the end of FY10. AeroVironment is expected to conduct flight operations from the range for 42 weeks during this annual period.

BERKELEY FLIGHT TESTING

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: University of California-Berkeley

SUMMARY: This statement of work documents specific tasks to be performed by NPS, through its prime contractor, Caltech, in support of CIRPAS' activities in support of the University of California-Berkeley's Flight Testing Program. Berkeley will fly BAT and Sig Rascal UAVs as part of its UAV development program. CIRPAS will provide facility and personnel support.

DESERT HAWK FLIGHT TRAINING

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: Lockheed Martin Maritime and Sensors-Tactical System

OBJECTIVE: To provide pre-flight coordination, flight coordination, range management, flight safety and facility management of Lockheed Martin's activities at the CIRPAS facility, and to ensure compliance with all CIRPAS and Caltech policies and procedures.

DESERT TALON

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: Marine Aviation Weapons and Tactics

SUMMARY: CIRPAS will assist with reconnaissance and surveillance imagery from the Pelican configured as a UAV surrogate with a Predator EO-IR payload. More than eighty percent of the funds required to support this flight activity will be sent to a contractor. The contractor is required to provide logistics and flight support for this project.

CIRPAS

EMERALD WARRIOR

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: Air Force Special Operations Command

OBJECTIVE: To support Emerald Warrior 09-1 with the Pelican from 30 January to 13 February 2009 at Hurlburt Air Force Base, Florida. The Pelican SUAV will support Emerald Warrior 09-1 with 58 mission-flight hours (30 ferry-flight hours). More than eighty percent of the funds required to support this flight activity will be sent to a contractor. The contractor is required to provide logistics support for this project.

EVERGREEN SCAN EAGLE FLIGHT-TRAINING SUPPORT

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: Evergreen Helicopters, Inc.

OBJECTIVE: To provide pre-flight coordination, flight coordination, range management, flight safety and facility management of Evergreen's activities at the CIRPAS SUAV range; and to ensure compliance with all CIRPAS and Caltech policies and procedures.

HART UAV TESTING AT CAMP ROBERTS

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: To support HART flight testing at the CIRPAS UAV airfield at Camp Roberts, California. CIRPAS provides range safety support and access to office, hangar and communications facilities. More than eighty percent of the funds required to support this flight testing will be sent to a contractor. The contractor is required to provide logistics support for this project.

LOCKHEED MARTIN SUAV FLIGHT RANGE USE

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: Lockheed Martin Tactical Systems

OBJECTIVE: To provide pre-flight coordination, flight coordination, range management, flight safety and facility management of Lockheed Martin's activities at the CIRPAS facility; and to ensure compliance with all CIRPAS and Caltech policies and procedures.

MWR SUPPORT FOR LTPO PAC-3 TESTING AT THE WHITE SAND MISSILE RANGE

Robert T. Bluth, Research Associate

Center for Interdisciplinary Remotely Piloted Aircraft Studies

Sponsor: Defense Threat Reduction Agency

OBJECTIVE: To support LTPO PAC-3 FT 7-2 with the MWR observations in February 2009 at White Sand Missile Range. The MWR will observe the intercept of a target reentry vehicle containing an MDA payload. More than eighty percent of the funds required to support this flight activity will be sent to a contractor. The contractor is required to provide logistics support for this project.

CIRPAS

THE NAVAL POSTGRADUATE SCHOOL SMALL BUSINESS INNOVATIVE RESEARCH PROGRAM SUPPORT

Robert T. Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Office of Naval Research

OBJECTIVE: To support the Office of Naval Research Small Business Innovative Research (SBIR) program in the development and management of SBIR.

PILOT TRAINING SUPPORT

Robert T. Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: General Atomics Aeronautical Systems, Inc.

OBJECTIVE: To provide training support and flight services.

SABER FOCUS PGCS SUPPORT

Robert T. Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Naval Air Systems Command

OBJECTIVE: To support Navy Predator-B UAV flight operations with the CIRPAS PGCS for Saber Focus project.

SCAN EAGLE FLIGHT TESTING

Robert T. Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Insitu, Inc.

SUMMARY: This statement of work documents specific tasks to be performed by the Naval Postgraduate School/CIRPAS in support of CIRPAS' activities in support of Insitu flight testing. Insitu wants to fly the Scan Eagle unmanned, aerial vehicle (UAV) as part of its UAV training and education program. CIRPAS will provide facility and personnel support.

SCAN EAGLE OPERATIONS AT CAMP ROBERTS

Robert T. Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Naval Special Warfare Group One

OBJECTIVE: To support three weeks of Scan Eagle flight testing at the CIRPAS UAV airfield at Camp Roberts, California, without range safety support. CIRPAS provides range safety support and access to office, hangar, and communications facilities. More than eighty percent of the funds required to support this flight testing will be sent to a contractor. The contractor is required to provide logistics support for this project.

CIRPAS

SUAV RANGE USE

Robert T. Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: AeroVironment, Inc.

OBJECTIVE: To provide pre-flight coordination, flight coordination, range management, flight safety, and facility management of AeroVironment's activities at the CIRPAS SUAV range; and to ensure compliance with all CIRPAS and Caltech policies and procedures.

TAMDAR PAYLOAD SUPPORT

Robert T. Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Airdat, L.L.C.

OBJECTIVE: To address the TAMDAR activities, including pre-mission activities: the Naval Postgraduate School/CIRPAS through its prime contractor, Caltech, will support pre-deployment activities via telecom. These activities include, but are not limited to, technical support for payload and range/ATC coordination and mission planning.

TOYON UNICORN UAV FLIGHT TESTING

Robert T. Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Toyon Research Corporation

OBJECTIVE: The Naval Postgraduate School (NPS)/CIRPAS, through its primary contractor, CalTech, will provide pre-flight coordination, flight coordination, range management, flight safety, and facility management of Toyon's flight testing activities at the CIRPAS facility, including ensuring compliance with all CIRPAS and CalTech policies and procedures.

DEPLOYMENT POOL FUNDING FOR THE CIRPAS TWIN OTTER AIRCRAFT IN SUPPORT OF THE NSF-APPROVED PHYSICS OF STRATOCUMULUS TOPS (POST) EXPERIMENT

Hafliði H. Jonsson, Research Associate Professor
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: National Science Foundation

OBJECTIVE: To provide meteorological instruments to the project, along with cloud and aerosol probes; to integrate a suite of instruments to measure fast temperature, fast liquid water, high-resolution drop sizes, CCN, and radiation, among other things; to provide office, lab, and meeting space for the duration of the experiment.

NPS/CIRPAS SUPPORT OF THE CALNEX EXPERIMENT IN 2010

Hafliði H. Jonsson, Research Associate Professor
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: National Oceanic and Atmospheric Administration

OBJECTIVE: To bring the CIRPAS Twin Otter and a team of flight operations and scientific personnel to Ontario, California, to participate in the CalNEX project. The plane will carry CIRPAS instrumentation and instruments provided by other project participants, and will measure meteorological and aerosol properties above and around Los Angeles.

NPS/CIRPAS SUPPORT OF OFFICE OF NAVAL RESEARCH AIRBORNE RESEARCH ACTIVITIES

Hafliði H. Jonsson, Research Associate Professor
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Office of Naval Research

OBJECTIVE: To support the airborne research objectives of the Office of Naval Research in the year 2009. Two research projects have independently requested the support of CIRPAS' personnel, instrumentation, and aircraft.

NPS/CIRPAS SUPPORT OF OFFICE OF NAVAL RESEARCH AIRBORNE RESEARCH OBJECTIVES

Hafliði H. Jonsson, Research Associate Professor
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Office of Naval Research

SUMMARY: Naval Postgraduate School/CIRPAS support of Office of Naval Research-funded field campaigns.

THE RACORO FIELD CAMPAIGN

Hafliði H. Jonsson, Research Associate Professor
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Department of Energy

SUMMARY: Long-term continuous characterization of cumulus cloud fields in Oklahoma.

**CENTER FOR
INTERDISCIPLINARY REMOTELY
PILOTED AIRCRAFT STUDIES**

**2009
Faculty Publications
and Presentations**

JOURNALS

Hsieh, W.C., Jonsson, H., Wang, L.-P., Buzorius, G., Flagan, R.C., Seinfeld, J.H., et al., "On the Representation of Droplet Coalescence and Autoconversion: Evaluation using Ambient Cloud Droplet Size Distributions," *Journal of Geophysical Research*, 114, D07201, doi:10.1029/2008JD010502, 2009.

Hsieh, W.C., Nenes, A., Flagan, R.C., Seinfeld, J.H., Buzorius, G., and Jonsson, H., "Parameterization of Cloud Droplet Size Distributions: Comparison with Parcel Models and Observations," *Journal of Geophysical Research*, 114, D11205, doi:10.1029/2008JD011387, 2009.

Lance, S., Nenes, A., Mazzoleni, C., Dubey, M., Gates, H., Varutbangkul, V., et al., "CCN Activity, Closure, and Droplet Growth Kinetics of Houston Aerosol during the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS)," *Journal of Geophysical Research*, 114, D00F15, doi:10.1029/2008JD011699, 2009.

Lu, M.-L., Sorooshian, A., Jonsson, H.H., Feingold, G., Flagan, R.C., and Seinfeld, J.H., "Marine Stratocumulus Aerosol - Cloud Relationships in the MASE - II Experiment: Precipitation Susceptibility in Eastern Pacific Marine Stratocumulus," *Journal of Geophysical Research*, 114, D24203, doi: 10.1029/2009JD012774, 2009.

Murphy, S.M., Agrawal, H., Sorooshian, A., Padro, L.T., Gates, H., Hersey, S., et al., "Comprehensive Simultaneous Shipboard and Airborne Characterization of Exhaust from a Modern Container Ship at Sea," *Environmental Science and Technology*, 2009.

Sorooshian, A., Padro, L.T., Nenes, A., Feingold, G., McComiskey, A., Hersey, S.P., et al., "On the Link between Ocean Biota Emissions, Aerosol, and Maritime Clouds: Airborne, Ground, and Satellite Measurements off the Coast of California," *Global Biogeochemical Cycles*, 23, GB4007, doi:10.1029/2009GB003464, 2009.

Wang, J., Daum, P.H., Yum, S.S., Liu, Y., Senum, G.I., Lu, M.-L., et al., "Observations of Marine Stratocumulus Microphysics and Implications for Processes Controlling Droplet Spectra: Results from the Marine Stratus/Stratocumulus Experiment," *Journal of Geophysical Research*, 114, D18210, doi:10.1029/2008JD011035, 2009.

**NPS–USSOCOM
FIELD EXPERIMENTATION
PROGRAM**

FIELD EXPERIMENTATION PROGRAM—USSOCOM

OVERVIEW:

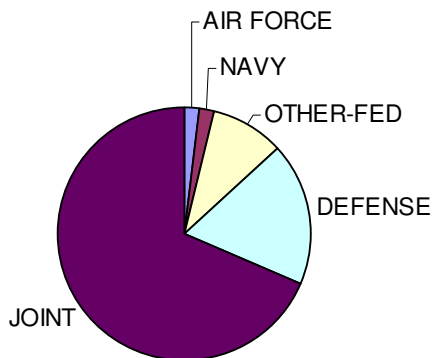
The Naval Postgraduate School Field Experimentation Program began in FY02 with the goal of providing an opportunity for students and faculty to evaluate some of their latest technologies in an operational environment and, when appropriate, to rapidly transition them to the warfighter. Today, the United States Special Operations Command (USSOCOM), the United States Naval Postgraduate School (NPS), and the Biometrics Task Force (BTF) conduct field experiments at multiple locations: Camp Roberts, California; Fort Hunter Liggett, California; Camp Dawson, West Virginia; Camp Atterbury, Indiana; and the ocean/port/riverine area of San Francisco Bay.

The primary objectives of the program are to experimentally explore the viability of new SOF technology concepts as solutions for identified current and future capability gaps; to provide a venue to rapidly assess, develop, counter, and exploit emerging capabilities; to provide and maintain an evolving, flexible, and adaptive plug-and-play infrastructure; and to provide a unique education and research environment for students and faculty at NPS. Secondary objectives include examining dual-use capabilities for homeland security, stabilization, reconstruction, disaster relief/humanitarian assistance, and for other government agencies.

These goals are accomplished by providing a unique field experiment venue in which innovation and collaboration between the Department of Defense, government agencies, industry, and universities are encouraged, and in which SOF operator participation and feedback are utilized. The Camp Roberts/Fort Hunter Liggett/Camp Atterbury/Camp Dawson portion focuses on urban and rural terrain, whereas the San Francisco Bay/European and other maritime locations focus on maritime interdiction operations, port security, and riverine operations. The major emphasis at Camp Roberts and Fort Hunter Liggett is on pre-requirements experimentation and rapid response to USSOCOM component command requests. The Camp Atterbury emphasis is on SOF/first responder concepts, training, and evaluations of newly available technologies for near-term utilization. Camp Dawson emphasizes untethered biometrics collection and related communications.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Field Experimentation Program—USSOCOM is provided below:



Size of Program: \$2.5M

FIELD EXPERIMENTATION PROGRAM—USSOCOM

Alexander Bordetsky
Associate Professor
Department of Information Sciences
831-656-2287
abordets@nps.edu

Raymond Buettner
Associate Professor
Department of Information Sciences
831-656-3387
rrbuettmn@nps.edu

LTC Lee Ewing, USA
Assistant Professor
Department of Operations Research
831-656-3040
plewing@nps.edu

Nancy M. Haegel
Distinguished Professor
831-656-3954
nmhaegel@nps.edu

Anthony J. Healey
Distinguished Professor and Director of
Center for AUV Research
Department of Mechanical and Aerospace
Engineering
831-656-3462
healey@nps.edu

Ed Lesnowicz
Research Associate
Department of Operations Research
831-656-2599
ejlesnow@nps.edu

John McEachen
Professor, Department of Electrical and
Computer Engineering
831-656-3652
mceachen@nps.edu

Richard C. Olsen
Professor
831-656-2019
olsen@nps.edu

FIELD EXPERIMENTATION PROGRAM—USSOCOM

TNT/CENETIX STUDENT RESEARCH FOR USSOCOM CENTER FOR NETWORKS AND COMMUNICATIONS

Alex Bordetsky, Associate Professor
Department of Information Sciences
Sponsor: U.S. Special Operations Command

OBJECTIVE: To provide research for USSOCOM problems at the Center for Networks and Communications.

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – THE AERIAL SEARCH AND OPTIMIZATION MODEL

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps, to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – HUMAN SYSTEMS INTERFACE

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

FIELD EXPERIMENTATION PROGRAM—USSOCOM

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – INDIVIDUAL IDENTITY FRIEND OR FOE

**Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command**

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – INFORMATION TECHNOLOGY

**Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command**

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – MANAGEMENT

**Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command**

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – METEOROLOGY

**Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command**

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

FIELD EXPERIMENTATION PROGRAM—USSOCOM

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – PARAFOIL

Raymond R. Buettner, Jr., Associate Professor

Center for Defense Technology and Education for the Military Services

Sponsor: U.S. Special Operations Command

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – SCAN EAGLE

Raymond R. Buettner, Jr., Associate Professor

Center for Defense Technology and Education for the Military Services

Sponsor: U.S. Special Operations Command

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

A FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS – UNMANNED AIR SYSTEMS

Raymond R. Buettner, Jr., Associate Professor

Center for Defense Technology and Education for the Military Services

Sponsor: U.S. Special Operations Command

OBJECTIVE: To explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF applications in a field environment.

GPS-DENIED GEOPOSITIONING FOR UNMANNED AIRCRAFT SYSTEMS USING TELEVISION SIGNALS OF OPPORTUNITY

Raymond R. Buettner, Jr., Associate Professor

Center for Defense Technology and Education for the Military Services

Sponsor: Global Positioning Systems Wing

OBJECTIVE: To investigate the capability to utilize signals of opportunity to geoposition unmanned aircraft systems independent of GPS availability.

FIELD EXPERIMENTATION PROGRAM—USSOCOM

(U) GPS-DENIED GEOPOSITIONING FOR UNMANNED AIRCRAFT SYSTEMS USING TELEVISION SIGNALS OF OPPORTUNITY

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: Naval Air Warfare Center Aircraft Division

OBJECTIVE: To investigate the capability to utilize signals of opportunity to geoposition unmanned aircraft systems independent of GPS availability.

(U) GPS-DENIED GEOPOSITIONING FOR UNMANNED AIRCRAFT SYSTEMS USING TELEVISION SIGNALS OF OPPORTUNITY

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: To investigate the capability to utilize signals of opportunity to geoposition unmanned aircraft systems independent of GPS availability.

GPS-DENIED NAVIGATION FOR UNMANNED AIRCRAFT SYSTEMS

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command

OBJECTIVE: To assemble, integrate, and test a GPS-independent, unmanned aircraft system geopositioning capability that could transmit to SAFC sensor platforms and other systems.

THE JIEDDO TECHNICAL GAMING TEAM INITIATIVE: RED AND BLUE MODELING AND SIMULATION

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To support two major modeling and simulation tasks aimed at helping to advance the technical gaming process. These major tasks include live experimentation and exploration of the feasibility of using a classified, web-based, high-power computing (HPC) system for accelerating the construction of surrogate models from physics-based models developed under TGT modeling and simulation efforts.

Task 1: Live Experimentation. The Camp Roberts/Hunter-Liggett field experimentation facilities will be used to collect high-quality datasets in support of the TOT modeling effort.

Task 2: Classified HPC Support for TOT Surrogate Model Construction. The Naval Postgraduate School (NPS) will coordinate with TOT elements to explore the feasibility of using USG-provided, classified, web-based, HPC systems to accelerate the development and testing of surrogate models currently under development. The objective is to implement the same surrogate process employed under Spiral I using the HPC systems, potentially providing significant time savings in producing surrogate models from the physics-based models.

FIELD EXPERIMENTATION PROGRAM—USSOCOM

NSA SIPRNET CONNECTIVITY AND UTILIZATION FOR THE CAMP ROBERTS FACILITY USSOCOM-NPS FIELD EXPERIMENTATION COOPERATIVE

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: National Security Agency

OBJECTIVE: To add a SIPR capability to the TOC at Camp Roberts; and to utilize the new capability to link forward-deployed SOF and tactical data from the field experiments to the NSA, USSOCOM, and other appropriate commands.

OPERATIONAL AND MAINTENANCE SUPPORT FOR THE FIELD EXPERIMENTATION PROGRAM FOR SPECIAL OPERATIONS FORCES

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: U.S. Special Operations Command

OBJECTIVE: To support efforts to explore the viability of new Special Operations Forces (SOF) technology concepts as solutions for identified current and future capability gaps; to provide a venue for short-fused experimentation requirements; and to support efforts to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF.

SCAN EAGLE PURCHASE FOR RESEARCH AND DEVELOPMENT SUPPORT AT THE USSOCOM-NPS EXPERIMENTATION TNT EXERCISE

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: National Security Agency

OBJECTIVE: To purchase a new SCANEAGLE UAS vehicle and spare parts from Insitu, Inc. to replace a Naval Postgraduate School SCANEAGLE that is being provided to NSAIS 145 for a quick reaction capability research and development deployment to Afghanistan in support of military operations.

TECHNICAL SUPPORT FOR THE NAVAL POSTGRADUATE SCHOOL FIELD EXPERIMENTATION PROGRAM

Raymond R. Buettner, Jr., Associate Professor
Center for Defense Technology and Education for the Military Services
Sponsor: Office of the Secretary of Defense

OBJECTIVE: To support efforts to explore the viability of new technology concepts as solutions for identified current and future capability gaps for the Special Operations Forces (SOF) and HLD communities; to provide a venue for short-fused experimentation requirements; and to support efforts to provide a unique, interdisciplinary, graduate-education experience for Naval Postgraduate School (NPS) students and research opportunities for NPS faculty in which the latest technologies, concepts of operation, and human systems integration are evaluated for SOF/HLD applications in a field and maritime environment.

FIELD EXPERIMENTATION PROGRAM—USSOCOM

INTERAGENCY TASK FORCE SOCIAL NETWORK FUNCTIONAL ANALYSIS

Lee Ewing, Assistant Professor
Department of Mechanical and Aerospace Engineering
Sponsor: U.S. Special Operations Command

OBJECTIVE: To research and develop appropriate optimization tools and use them to assist the chief of the USSOCOM Interagency Task Force in the fulfillment of the division's mission.

NEXT-GENERATION REMOTELY TRIGGERED PLED EMITTERS FOR IFF FOR SPECIAL OPERATIONS FORCES

Nancy M. Haegel, Professor
Department of Physics
Sponsor: U.S. Special Operations Command

OBJECTIVE: To design next generation IFF patch for Special Operations Forces.

ENVIRONMENTAL CHARACTERIZATION AND FIELD TESTING FOR THE USSOCOM BLUE LIGHT SPECIAL

Anthony J. Healey, Distinguished Professor
Department of Mechanical and Aeronautical Engineering
Sponsor: U.S. Special Operations Command

OBJECTIVE: To support initial field testing of the USSOCOM Blue Light Special underwater communications system in Monterey Bay. Using a REMUS autonomous underwater vehicle, the Naval Postgraduate School (NPS) will measure the environmental characteristics in the BLS system's operating area to assess the optical properties of the surroundings seawater. NPS will then conduct several underwater communications experiments between a fixed location and a mobile platform to measure the BLS data rate.

A GRADUATE STUDIES RESEARCH PROGRAM

Ed Lesnowicz, Research Associate
Department of Operations Research
Sponsor: U.S. Special Operations Command

OBJECTIVE: To establish the process to investigate and analyze various USSOCOM programs and processes related to acquisition, financial, and personnel management. This will be executed as a series of graduate studies projects jointly conducted by the Naval Postgraduate School Operations Research faculty and students. This project will establish the framework and format for the program.

JOINT THREAT WARNING SYSTEM (JTWS) FY09: THREAT SIGNALS PROJECTION AND RESEARCH

John C. McEachen, Professor
Department of Electrical and Computer Engineering
Sponsor: U.S. Special Operations Command

OBJECTIVE: To establish the JTWS, including assessment of future technologies and threats for defining SOF SIGINT requirements, developing distributed direction finding and geolocation algorithms for applications to JTWS, to include leveraging algorithms of the Cryptological Research Laboratory for analysis of signals of interest to USSOCOM, integrating techniques in computer network operations into SOF operational systems and investigating efforts with wireless sensor and SMART dust programs of integration into SOF operations systems.

FIELD EXPERIMENTATION PROGRAM—USSOCOM

REMOTE SENSING CENTER DEVELOPMENT AND SUPPORT

Richard C. Olsen, Professor

Department of Physics

Sponsor: Naval Postgraduate School

SUMMARY: To develop and operate a remote sensing center. These funds were used in 2009 to support research, academic development, and outreach activities. The most visible effort was the booth at GEOINT 2009, which was shared in partnership with AFIT. The Remote Sensing Center showcased research efforts and provided information on academic programs. Some of the funds were used for an innovative research effort in the use of social network analysis for technology (LIDAR). These funds enable the startup of the Remote Sensing for Intelligence degree program.

FIELD EXPERIMENTATION PROGRAM – USSOCOM

**2009
Faculty Publications
and Presentations**

FIELD EXPERIMENTATION PROGRAM—USSOCOM

Publications and presentations for Field Experimentation Program—USSOCOM faculty members are listed in their respective home departments.

**NATIONAL SECURITY
INSTITUTE**

**DANIEL C. BOGER
EXECUTIVE DIRECTOR**

NATIONAL SECURITY INSTITUTE

OVERVIEW:

The National Security Institute (NSI) is a partnership of three entities – the Naval Postgraduate School, the University of California at Santa Barbara, and the Lawrence Livermore National Laboratory – each recognizing that the new era of research and development will require the complete engagement of talent from academia, national laboratories, and the private sector.

Under NSI, a superior class of joint research programs is being created from the combination of intellectual and technological capabilities of these three institutions. New and innovative research programs will create unparalleled opportunities and will attract the best M.S. and Ph.D. students and post-doctoral fellows – all focused within the critical skills areas identified by the Departments of Defense, Energy, and Homeland Security. These activities will lead many of these graduate students and post-doctoral fellows into careers that support national security science and technology in national laboratories or defense and security industries.

MISSION:

The mission of the National Security Institute is to combine the scholarship and expertise of top scientific institutions in service to national, homeland, and global security, while engaging the next generation of graduate students in vital defense and homeland security research and development, field experimentation, and interdisciplinary student research.

PARTNERS:

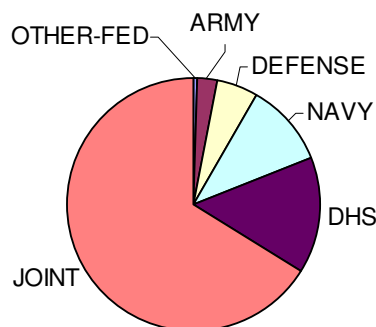
The Naval Postgraduate School (NPS) is an academic institution whose emphasis is on study and research programs relevant to the Navy's interests, as well as to the interests of other arms of the Department of Defense. The programs are designed to accommodate the unique requirements of the military.

The Lawrence Livermore National Laboratory (LLNL) is one of the nation's foremost applied-science and engineering laboratories. LLNL's defining responsibility is national security, with missions that include stockpile stewardship, nonproliferation, and multidisciplinary research to enhance national security.

The University of California at Santa Barbara (UCSB) houses eight national centers and institutes, with a top-twenty engineering school, five Nobel laureates, and substantial federal funding in critical research.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the National Security Institute is provided below:



Size of Program: \$5.6M

NATIONAL SECURITY INSTITUTE

Daniel C. Boger
Executive Director
831-656-3671
dboger@nps.edu

Ed Lesnowicz
Associate Director–Research
831-656-2599
ejlesnow@nps.edu

John Powers
Associate Director–Education
831-656-2679
jpowers@nps.edu

Jomana Amara
Assistant Professor
831-656-3591
jhamara@nps.edu

Alexander Bordetsky
Associate Professor
Department of Information
Sciences
831-656-2287
abordets@nps.edu

Gordon H. Bradley
Professor
831-656-2359
gbradley@nps.edu

Raymond Buettner
Associate Professor
Department of Information
Sciences
831-656-3387
rrbuettnn@nps.edu

Walter Christman
Associate Professor
Office of the Provost
wlchrist@nps.edu

Peter C. Chu
Professor
831-656-3688
pcchu@nps.edu

James Ehlert
Research Associate
Department of Information
Sciences
831-656-3002
jfehlert@nps.edu

William Fox
Professor
831-656-3753
wpfox@nps.edu

Simson Garfinkel
Associate Professor
831-656-7602
slgarfin@nps.edu

Heather S. Gregg
Assistant Professor
Department of Defense
Analysis
831-656-3689
hsgregg@nps.edu

Thomas J. Housel
Professor
Department of Information
Sciences
831-656-7657
tjhousel@nps.edu

David C. Jenn
Professor
831-656-2254
jenn@nps.edu

Thomas Johnson
Professor
831-656-3190
thjohnso@nps.edu

Magdi N. Kamel
Associate Professor
Department of Information
Sciences
831-656-2494
mkamel@nps.edu

Jeffrey E. Kline
Senior Lecturer
Department of Operations
Research
831-656-7946
jekline@nps.edu

Mathias N. Kolsch
Assistant Professor
Department of Computer
Science
831-656-3402
kolsch@nps.edu

Kyle Y. Lin
Department of Operations
Research
831-656-2648
kylin@nps.edu

Thomas W. Lucas
Associate Professor
Department of Operations
Research
831-656-3039
twlucas@nps.edu

Perry McDowell
Lecturer
Department of Computer
Science
831-656-7591
mcdowell@nps.edu

James Bret Michael
Associate Professor
Department of Computer
Science
831-656-2655
bmichael@nps.edu

NATIONAL SECURITY INSTITUTE

Daniel A. Nussbaum
Visiting Professor
831-656-2387
dnussbaum@nps.edu

R. Chris Olsen
Professor
Department of Physics
831-656-2019
olsen@nps.edu

Phillip E. Pace
Professor
Department of Electrical and
Computer Engineering
831-656-3286
pace@nps.edu

Eugene Paulo
Associate Professor
831-656-3452
eppaulo@nps.edu

Susan M. Sanchez
Professor
831-656-2780
ssanchez@nps.edu

Lyn Whitaker
Associate Professor
Department of Operations
Research
831-656-3482
lwhitaker@nps.edu

R. Kevin Wood
Distinguished Professor
831-656-2523
kwood@nps.edu

NATIONAL SECURITY INSTITUTE

THE USE OF IMPROVISED EXPLOSIVE DEVICES AS A STRATEGIC WEAPON ON A SUBNATIONAL LEVEL IN IRAQ

**Jomana Amara, Assistant Professor of Economics
Defense Resources Management Institute
National Security Institute**

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: This research is a follow-on to “Scale Invariance with Specific Applications to IED Violence in Iraq 2003-2007.” The research will be extended to investigate the dynamics of violence at the provincial level. The research will focus on each of the 18 provinces in Iraq and further disaggregate the analysis by type of weapon system.

Recent analyses suggest that other dimensions of violent conflict adhere to a power law distribution. Casualties in intra-state conflicts in Iraq and Columbia and non-G7 global terrorism also appear to converge to a power law distribution. Previous analyses found that fatalities per incident in Iraq appear to be distributed in a similar fashion to those resulting from non-G7 terrorism, suggesting that violence in both cases is characterized by a large number of low-impact events.

DEPARTMENT OF HOMELAND SECURITY SCIENCE AND TECHNOLOGY SUPPORT

**Daniel C. Boger, Professor
National Security Institute
Sponsor: Department of Homeland Security**

OBJECTIVE: The U.S. Department of Homeland Security (DHS) is committed to using cutting-edge technologies and scientific talent in its quest to make America safer. The DHS Directorate of Science and Technology (S&T) is tasked with researching and organizing the scientific, engineering, and technological resources of the United States and leveraging these existing resources into technological tools to help protect the homeland.

AN INTRODUCTION TO IMPROVISED EXPLOSIVE DEVICE THREAT, DATA, ANALYSIS, AND RESEARCH

**Gordon H. Bradley, Professor
National Security Institute
Sponsor: Joint Improvised Explosive Device Defeat Organization**

OBJECTIVE: To offer three tutorials (both classified and unclassified) on the improvised explosive device (IED) threat, data, analysis, and research. The tutorials will be open to Naval Postgraduate School faculty and students. Each tutorial will repeat the same basic information and discuss current IED development and trends.

PHASE I TECHNOLOGICAL SUPPORT AND LIVE EXPERIMENTATION IN SUPPORT OF NPS-JOINT IMPROVISED EXPLOSIVE DEVICE DEFEAT ORGANIZATION MODELING AND SIMULATION

**Raymond R. Buettner, Jr., Associate Professor
National Security Institute
Sponsor: Joint Improvised Explosive Device Defeat Organization**

OBJECTIVE: This project builds upon the mature capability to conduct live experiments, and the ongoing modeling and simulation expertise resident within the Naval Postgraduate School. The data and insights generated from this effort will be incorporated into the Joint Improvised Explosive Device Defeat Organization-TGT reports that are provided to the operational forces, and to the developers of technologies that support operational forces. It is anticipated that the work will enhance the analysis of Red/Blue teaming activities. This research effort may include insights from and provide input to classified environments, including TS/SCI programs.

NATIONAL SECURITY INSTITUTE

TRANSFORMATIONAL C2 SERVICES FOR UNDERSTANDING THE IMPACT OF GLOBALIZATION ON STABILITY AND SECURITY

Walter L. Christman, Associate Professor
Office of the Provost

National Security Institute

Sponsor: Space and Naval Warfare Systems Center-Charleston

OBJECTIVE: To establish a collaboration laboratory (Co-Lab) focused on open technology development initiatives and their potential impact on issues of globalization, stability, and security. The Co-Lab will provide a venue for exploring best practices across disciplines regarding open-source community engagement and technology development between entities.

RED TEAM MARITIME IMPROVISED EXPLOSIVE DEVICE

Peter C. Chu, Professor
Department of Oceanography
National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To develop a six degree-of-freedom model that can be used in the SEA 14 cohort exercises and other port and littoral simulations. The model will suggest an effective target range for destroying an underwater improvised explosive device. This model and the data developed will be incorporated into various models and simulations used to evaluate and assess the required capabilities for organizations conducting riverine, naval, or port operations.

SENSING AND IDENTIFYING PEOPLE CARRYING WIRES ON THEIR BODY FOR IMPROVISED EXPLOSIVE DEVICE DETONATION

William P. Fox, Professor
Department of Defense Analysis
National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: The project will begin with the radar effort by constructing physical models of a suspect with specific “typical” patterns of wires attached and modeling the radar cross-section using the numerical electromagnetic code (NEC) in a standard software package. The main objective of the radar system is to single out subjects that have wires on their person. The radar will attempt to discriminate (at a safe distance) between suspects with wires and those without wires by the enhanced radar cross-section due to the wires. This effort will likely require a frequency agile radar that can sense the wires on a frequency that is resonant with the wire structure.

ADAPTION AND TESTING OF AUTOMATED MEDIA EXPLOITATION TOOLS

Simson L. Garfinkel, Associate Professor
National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To develop a Document and Media Exploitation (DOMEX) tool to exploit improvised explosive device-planting networks. Captured hard drives, USB memory sticks, and other data-carrying devices can be analyzed for information that is used to understand, target, and eventually destroy enemy networks.

NATIONAL SECURITY INSTITUTE

USING ENDURING EMPLOYMENT PROGRAMS TO COMBAT IMPROVISED EXPLOSIVE DEVICE NETWORKS

**Heather S. Gregg, Professor
National Security Institute**

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To deliver an easy to read, easy to access manual that offers employment menus, goals, requirements, and resources needed to implement projects at each phase. The manual will be designed for a program officer, S-7, S-9, and S-2 to use in coordination with their overall targeting goals in their area of operations.

The overall goal of the project is to attack the networks that engage in insurgent activity and use improvised explosive devices; this will be accomplished by positively interacting with the population, strengthening the pillars of stabilization – particularly security, governance, and economic development – and offering vulnerable segments of the population (young men) alternatives to engaging in insurgent activity. The employment manual, therefore, is a means for achieving strategic ends; U.S. troops can use employment to weaken insurgent networks while strengthening the governing capabilities of the host nation.

ACHIEVING INTEROPERABILITY IN HOMELAND SECURITY COMMUNICATIONS AND OPERATIONS: A “MODEL COUNTY” FIELD TEST

**Thomas J. Housel, Professor
National Security Institute**

Sponsor: Department of Homeland Security

OBJECTIVE: To examine various networking-information systems’ interoperability problems in combination with various methods for information sharing in a “model county” field-test context. In the model county scenario, the principal investigator will be able to examine a variety of planning issues that guide responders in daily and emergency situations.

CONTINUATION OF THE TRIAL IMPLEMENTATION: PERFORMANCE ACCOUNTING/TOOLS TO SUPPORT THE BUDGETING ALLOCATION PROCESS FOR A SIGNAL-INTELLIGENCE COLLECTION SYSTEM

**Thomas J. Housel, Professor
Department of Information Sciences**

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To implement KVA software for the purpose of collecting performance (return on investment) information on CCOPS signal-intelligence equipment and the KL process in general.

ESTIMATING THE VALUE OF OPTIONS IN THE ROLL-OUT OF ADVANCED CAPABILITIES BUILD 12 IN AN OPEN ARCHITECTURE ENVIRONMENT

**Thomas J. Housel, Professor
Department of Information Sciences**

Sponsor: Program Executive Office, Integrated Warfare Systems

OBJECTIVE: This project will be divided into three phases. PEO-IWS 1 may stop the project at the end of every phase, delay the state, or decide to continue to the next phase immediately.

Phase one is an ROI valuation and implementation of a project selected by PEO-IWS 1 personnel. This project will culminate with a report detailing the KVA+RO analysis for IWS upgrades using an OA approach. The results of this work will provide management with the capability to interpret ongoing ROI analysis on OA processes, as well as the means for valuing strategic, real options; identifying and selecting projects; and quantifying and mitigating risks for IWS development and acquisition processes enabled through the use of the OA approach. The RO analyses will include Monte Carlo Risk Simulation and

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project portfolio optimization and selection of the RO models based on parameter distributions derived by the KV analysis. The ongoing use of the KVA+RO methodology will enable continuous refinements of the option lattices based on changes to the KVA data over time. Training in the use of the KVA+RO methodology using the supporting software will be included if requested.

THE REIMBURSABLE DETAIL OF MILTON NENNEMAN

Thomas J. Housel, Professor

National Security Institute

Sponsor: Department of Homeland Security

OBJECTIVE: To document approval of, and terms and conditions for, the reimbursable detail for Mr. Milton Nenneman through 30 September 2010, unless further extended.

A COMMAND WIRE SENSOR

David C. Jenn, Professor

National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: The main effort will be focused towards an application, where detection of a wire is the objective and a high-resolution image is not required, so the data processing problem is reduced significantly. The major challenge will be to achieve a high probability-of-detection without a large number of false alarms. Tradeoffs of the sensor-system architecture will be investigated, and the system parameters that affect the performance of each architecture will be determined. The objective of this study is to examine possible sensor architectures and perform a first-cut simulation of the system tradeoffs to determine their suitability for wire detection.

DEVELOPING IMPROVISED EXPLOSIVE DEVICE COUNTER-NARRATIVES

Thomas Johnson, Professor

National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: At present, 49% of U.S. casualties in Afghanistan are caused by improvised explosive devices (IEDs) and explosively formed penetrators (EFPs), and that percentage is growing. IEDs and EFPs are a relatively new weapon in Afghanistan. In order to effectively counteract IEDs in Afghanistan, it is essential to understand their human masters and the narratives that drive them, and develop successful counter-narratives.

A STRATEGIC FRAMEWORK FOR WORLDWIDE IMPROVISED EXPLOSIVE DEVICE EVENTS

Thomas Johnson, Professor

National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: Information and data for the narrative will be derived from contemporary classified and unclassified sources that highlight current insurgent activity for the month. Information will be analyzed for trends and formatted to present a cogent picture of the strategic framework of activity related to significant improvised explosive device events. The classified report will include a hypothetical "road to war" scenario that is based on the current international situation.

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SEQUENTIAL PATTERN DETECTION AND A TIME SERIES MODEL FOR PREDICTING IMPROVISED EXPLOSIVE DEVICE ATTACKS, PHASE 1

Magdi N. Kamel, Associate Professor

National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To expand the previous effort to include the following tasks. First, to interpret and validate the resulting sequences to identify those sequences that are novel, useful, and actionable. To experiment with different algorithms and different data mining tools, such as the Automated Tactical Analysis of Crime (ATAC), to identify the most suitable ones. To incorporate additional events in the model as predictors of an improvised, explosive-device attack; these could include religious holidays, political events, and a breakdown of indiscriminate, religious leaders, and tribal leaders attacks by religious affiliation (e.g., Sunni versus Shia).

THE MARITIME DEFENSE AND SECURITY RESEARCH MANAGEMENT ACCOUNT

Jeffrey E. Kline, Senior Lecturer

National Security Institute

Sponsor: Naval Postgraduate School Directed Research

OBJECTIVE: To conduct, coordinate, and collaborate maritime defense and security research, experimentation, and information-exchange between partnership universities; federal, state, and local agencies; national laboratories; the maritime industry; and international partners through the National Security Institute.

SUMMARY: The Maritime Defense and Security Research Program (MDSRP) underwrites several major field experimentations at the Naval Postgraduate School (NPS), including the maritime interdiction experimentation by Tactical Network Topology (TNT), COASTS, and SEAWEB. Other programs funded under this umbrella include the GSEAS maritime domain awareness work and environmental impact on sensors. In 2008, the MDSRP also initiated the Maritime Information Sharing Task Force (MIST). MIST, co-sponsored with the Department of Transportation, held its first local symposium at the Port of Long Beach to obtain information on policy barriers to information exchange between commercial entities and government agencies. This research also supports faculty labor and travel to attend various maritime homeland defense and security conferences or host them at the Naval Postgraduate School (NPS). This account also allows NPS to publish and distribute the monthly SITREP e-newsletter, which reports country-wide research initiatives related to maritime security.

THE MARITIME INFORMATION SHARING TASKFORCE FY09 YEAR-END SUPPLEMENT- FUNDING PROPOSAL

Jeffrey E. Kline, Senior Lecturer

National Security Institute

Sponsor: Office of the Director of National Intelligence

OBJECTIVE: In order to successfully complete the work required before the end of FY09, supplemental funds are required. FY09-expiring funds have been offered by the Office of the Director of National Intelligence; the Maritime Information Sharing Taskforce has accepted the offer of funds.

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IMPROVING CREW THREAT AWARENESS BY AUGMENTED, SPHERICAL, INDIRECT VISION

**Mathias N. Kolsch, Assistant Professor
National Security Institute**

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: The Naval Postgraduate School Vision Lab utilizes synergistic effects based on other Vision Lab projects, including AR-VAST for registration of virtual data with video and another project that utilizes panoramic stereo-vision for depth estimation. Data collection trips are planned to determine ground truth in a controlled environment for evaluation. User studies will be conducted on campus; these studies involve Soldiers shortly after deployment to generate useful feedback.

COUNTER-NARCOTICS PROGRAM SUPPORT

**Ed Lesnowicz, Associate Director for Research
National Security Institute**

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To provide programs support personnel and research advice for the Counter-Narcotics/Counterterrorism Office.

THE GRADUATE RESEARCH STUDIES PROGRAM, PHASE I

**Ed Lesnowicz, Associate Director for Research
National Security Institute**

Sponsor: U.S. Special Operations Command

OBJECTIVE: To establish the process to investigate and analyze various U.S. Special Operations Command programs and processes related to acquisition, financial, and personnel management. This will be executed as a series of graduate studies projects jointly conducted by the Naval Postgraduate School Department of Operations Research (OR) faculty and OR graduate students. This project will establish the framework and format for the program.

JOINT IMPROVISED EXPLOSIVE DEVICE DEFEAT ORGANIZATION TECHNICAL GAMING TEAM INITIATIVE SUPPORT

**Ed Lesnowicz, Associate Director for Research
National Security Institute**

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To enhance and bridge capability gaps in the Joint Improvised Explosive Device Defeat Organization's (JIEDDO) research and development efforts. The Naval Postgraduate School (NPS) principal investigators (PIs) will coordinate directly with the JIEDDO Technical Gaming Team (TGT) Branch Chief (or designated representatives) to ensure that research activities and analyses are appropriate, relevant, and timely. In addition, the NPS PIs will designate a study lead for each internal study related to the execution of these tasks and supporting research. The result will be a set of recommendations for investment, fielding, and application of future systems and procedures closely aligned to JIEDDO's present and future strategic objectives. The primary emphasis will be on analyzing route clearance scenarios; IED systems modeling and analysis; and, experimentation and testing (live, virtual, and constructive environments). A secondary emphasis will be on IED networks and applying a cross-disciplinary approach to determine key nodes and arcs of the network that may be influenced. This research includes, but is not limited to, modeling and simulation, operations research, systems engineering, and other analyses, which will become deliverables to JIEDDO. NPS will use JIEDDO-approved operational scenarios, as well as data and intelligence incidents to perform these studies. NPS will use qualitative and quantitative methodologies that are transferable to JIEDDO.

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NAVAL POSTGRADUATE SCHOOL ACADEMIC SUPPORT TO THE JOINT IMPROVISED EXPLOSIVE DEVICE DEFEAT ORGANIZATION

Ed Lesnowicz, Associate Director for Research
National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To enhance and bridge capability gaps in the Joint Improvised Explosive Device Defense Organization (JIEDDO) research and development efforts. It further outlines anticipated deliverables and resources from the Naval Postgraduate School (NPS) that fulfill the requirements that correspond to this expanded support. The NPS principal investigator (PI) will coordinate directly with the JIEDDO Operations Research (ORSA) Division Chief and Technical Gaming Team (TGT) Branch Chief (or designated representative) to ensure that research activities and analyses are appropriate, relevant, and timely.

NAVAL POSTGRADUATE SCHOOL SUPPORT TO THE JOINT IMPROVISED EXPLOSIVE DEVICE DEFEAT TEST BOARD

Ed Lesnowicz, Associate Director for Research
National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: The activities of the Joint Improvised Explosive Device Defeat Test Board (JTB) in the effort to evaluate technologies and procedures to defeat improvised explosive devices (IEDs) produces significant testing, data analysis, modeling and simulation (M&S), and equipment-development challenges. The purpose of this agreement is to develop a collaboration with the Naval Postgraduate School (NPS) to leverage the educational and research capabilities of NPS in support of the JTB.

PEACE SUPPORT OPERATIONS MODEL SUPPORT TO III CORPS

Ed Lesnowicz, Associate Director for Research
National Security Institute

Sponsor: U.S. Army III CORPS

OBJECTIVE: To assist the Army's Third Corps in deployment training by assisting the Peace Support Operations Model and incorporating it into the training cycle with appropriate content and time intervals.

EXTENSION TO GAME-THEORETIC MODELS FOR JAMMING RCIEDS AND RED TEAMING

Kyle Y. Lin, Associate Professor
Department of Operations Research
National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: This project has two parts: 1) extension to the existing model, and 2) red teaming. The research techniques require inclusion of stochastic modeling, game theory, statistics, and optimization. The pertinent data may include, but is not limited to, characteristics of the current IED technology used by insurgents and the capability/characteristics of the state-of-the-art jammers. The researchers will also use open source data.

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COUNTERING THE IMPROVISED EXPLOSIVE DEVICE THREAT: EXPERIMENTATION AND ASSESSMENT OF STRATEGIES, SYSTEMS, AND EMPLOYMENT OPTIONS THROUGH SIMULATION

**Thomas W. Lucas, Associate Professor
Department of Operations Research
National Security Institute**

Sponsor: Joint Improvised Explosive Device Defeat Organization

SUMMARY: Improvised explosive devices (IEDs) are the weapon of choice for those actively battling U.S. and coalition forces around the world. In fact, IEDs are causing the majority of casualties to U.S. forces in Iraq and Afghanistan. Defeating the IED threat is essential to winning the war on terror. Furthermore, future threats that are overmatched in conventional combat will undoubtedly resort to this asymmetric tactic. Countering the IED threat is and will be fundamental to our nation's security. Towards that end, the Joint Improvised Explosive Device Defeat Organization (JIEDDO) was established. JIEDDO is addressing the IED threat on multiple fronts – from defeating the device, to attacking the network, to training the force.

This project will add to JIEDDO's ability to rapidly and efficiently conduct high-dimensional, computational experiments as part of an analysis campaign – thus enabling broader, more robust analytical support to operators and decision makers. This research will also improve the infrastructure that underpins this class of JIEDDO studies by improving the ability to rapidly build or extend models and scenarios, conduct computational experiments (through better design of experiments), and analyze/synthesize the output from multiple experimental tools.

DEVELOPING AND ASSESSING THE PEACE SUPPORT OPERATIONS MODEL

**Thomas W. Lucas, Associate Professor
Department of Operations Research
National Security Institute**

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: This research will be conducted within the SEED Center at the Naval Postgraduate School. SEED is an acronym for Simulation Experiments and Efficient Design; the SEED Center's mission is to advance the collaborative development and use of simulation experiments and efficient designs to provide decision-makers with timely insights on complex problems.

SIMULATION AND ANALYSIS OF COUNTER-IMPROVISED EXPLOSIVE DEVICE TECHNOLOGIES WITHIN THE LIVE EXPERIMENT CONDUCTED AT THE TALE EXERCISE IN NOVEMBER 2008

**Thomas W. Lucas, Associate Professor
Department of Operations Research
National Security Institute**

Sponsor: Joint Improvised Explosive Device Defeat Organization

SUMMARY: This research will be conducted within the SEED Center at the Naval Postgraduate School and the live test ranges located at Camp Roberts and Ft. Hunter Liggett, California. SEED is an acronym for Simulation Experiments and Efficient Design; the SEED Center's mission is to advance the collaborative development and use of simulation experiments and efficient designs to provide decision-makers with timely insights on complex systems and operations. It does this by teaming analysts, programmers, subject matter experts, and operators to enable the rapid creation and broad exploration of simulation experiments of new organizations, capabilities, and tactics.

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SIMULATION AND ANALYSIS SUPPORT OF THE TOTAL LIFE CYCLE MANAGEMENT WORKING GROUP'S STUDY REQUIREMENTS

Thomas W. Lucas, Associate Professor
Department of Operations Research
National Security Institute
Sponsor: U.S. Marine Corps Systems Command

OBJECTIVE: The development of modeling and simulation (M&S) to support Total Life Cycle Management (TLCM) is complex and requires a close examination of the factors involved and results obtained. The insights derived from M&S can contribute significantly to operational readiness and cost readiness. Consequently, research is needed to identify important data and key TLCM factors. The principal investigators will experiment with modeling tools and simulations for the purpose of assessing their accuracy and applicability and will participate in the development of a TLCM tool that best meets the needs of the logistical requirements of the U.S. Marine Corps.

MODELING AND SIMULATION SUPPORT TO THE NAVAL POSTGRADUATE SCHOOL JOINT IMPROVISED EXPLOSIVE DEVICE DEFEAT ORGANIZATION PROJECT

Perry McDowell, Lecturer
Department of Computer Science
National Security Institute
Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To examine how the Naval Postgraduate School Joint Improvised Explosive Device Defeat Organization (JIEDDO) team can use modeling and simulation to support the team's mission of providing support to JIEDDO and advising the JIEDDO team on M&S matters.

UNITED STATES MARINE CORPS PERFORMANCE PRICING MODEL

Daniel A. Nussbaum, Visiting Professor
Department of Operations Research
National Security Institute
Sponsor: U.S. Marine Corps Headquarters

OBJECTIVE: To provide U.S. Marine Corps (USMC) planners with an analytical tool to support sustainment requirements in the PPBE process. The focus of these efforts will be on: 1) reviewing current operating and support pricing models in use within the Department of Defense and their potential for transfer to the USMC Installation and Logistics Directorate for use as pricing models, and 2) developing a prototype pricing model that can be used to predict sustainment funding requirements.

GENERATING A SYSTEMS ARCHITECTURE ADDRESSING THE CAPABILITIES, REQUIREMENTS, AND TTPS FOR THE TRANSFORMABLE CRAFT

Eugene Paulo, Associate Professor
Department of Systems Engineering
National Security Institute
Sponsor: Office of Naval Research

OBJECTIVE: To 1) use systems engineering methods to provide a framework for the examination of technologies, tactics, and capabilities that can be used to determine how to best implement the Transformable Craft (T-Craft) as a sea-basing Innovative Naval Prototype; 2) develop an operational concept (OPCON) for T-Craft employment; 3) design functional and physical systems architectures, combining them with the OPCON, and leading to an operational architecture; 4) identify likely CONOPS, including specific scenarios, in order to provide context; 5) identify follow-on requirements for simulation-based analysis of alternatives; and 6) provide limited analysis of the proposed T-Craft electric drive.

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BUILDING AN ENVIRONMENT FOR EFFICIENT, CLASSIFIED, COMPUTATIONAL EXPERIMENTATION

Susan Sanchez, Professor

National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: The SEED Center for Data Farming will construct a classified computing cluster that will enable efficient, parallel processing of simulation experiments utilizing sensitive data and/or models. The classified cluster will have at least as much processing power as the existing, unclassified SEED Center cluster. Furthermore, it must be able to run the existing SEED Center models (like Pythagoras and iwars) utilizing the Center's advanced design of experiments. In addition, an assessment will be made on what is required to include JCATS in the system. If possible, JCATS (or other JIEDDO-approved simulations) will be integrated and a proof-of-concept analysis will be completed. The analysis will include a high-dimensional exploration of a scenario specified by JIEDDO. Other candidate models will be included pending an assessment of their feasibility and JIEDDO's interest.

INTEGRATION OF TACTICS WITH THE EMPLOYMENT OF MULTIPLE ISR CAPABILITIES TO COUNTER IMPROVISED EXPLOSIVE DEVICES

Susan Sanchez, Professor

National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: To leverage the resources of SEED (Simulation Experiments and Efficient Design) Center experimentation techniques to create an analysis of ISR capabilities and the associated tactics against terrorist forces that extensively employ improvised explosive devices. The insights gained from this project will help identify factors to improve the performance of the force, and provide indications where tactics, capabilities, and/or policies require further integration.

STATISTICAL MODELING OF IMPROVISED EXPLOSIVE DEVICE EVENTS AND BLUE FORCE ACTIVITIES IN A DYNAMIC ENVIRONMENT

Lyn R. Whitaker, Associate Professor

Department of Operations Research

National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: Statistical improvised explosive device (IED) work must begin with an intimate understanding the data and documentation of that understanding for future use. This includes cataloguing quantifiable exogenous and endogenous factors involving IED events for use in statistical models. As understanding increases, the principal investigators (PIs) will model relationships between IED events and Blue Force movements with data available early in 2008. Finally, the PIs propose to see how far modeling efforts can be taken in the direction of modeling the survivability of IED networks.

INTERDICTING THE IMPROVISED EXPLOSIVE DEVICE SUPPLY CHAIN

Kevin Wood Professor

National Security Institute

Sponsor: Joint Improvised Explosive Device Defeat Organization

OBJECTIVE: This research focuses on Joint Improvised Explosive Device Defeat Organization's contention that a more complete solution to the improvised explosive device (IED) problem can be achieved by intelligently interdicting the IED supply chain. Earlier work by the researchers has developed theoretical models for interdicting IED components as they are being smuggled through a generic

transportation network. One game-theoretic model for placing mobile inspection teams has been implemented in VBA (Visual Basic for Applications), together with a graphic interface based on Microsoft Excel.

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**2009
Faculty Publications
and Presentations**

NATIONAL SECURITY INSTITUTE

Publications and presentations for National Security Institute faculty members are listed in their respective home departments.

CENTER FOR ASYMMETRIC WARFARE

**Joyce Borgen
Deputy Director**

CENTER FOR ASYMMETRIC WARFARE

OVERVIEW:

The Center for Asymmetric Warfare (CAW) is a federal government organization established in 1999 in recognition of the need to support U.S. military forces and local/state/federal organizations in identifying, countering, and controlling the effects of asymmetric warfare (AW) in support of the Global War on Terrorism. CAW is committed to providing the best exercises, training, technology, and education in an integrated environment in an effort to enable participants to achieve their goals and objectives.

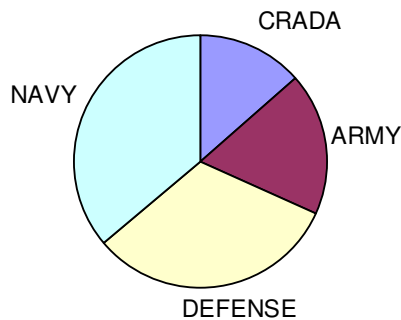
In 2008, CAW joined the Naval Postgraduate School (NPS) as a satellite division, located at Point Mugu, California, and is aligned under the National Security Institute. CAW has the flexibility to operate across the four institutes and four schools that make up NPS. It also allows CAW to capitalize on the expertise of many distinguished alumni, faculty, and students.

The CAW Difference. CAW builds exercises that include participants from local, state, federal, Department of Defense, military, and private sector entities.

CAW offers a multi-faceted team that has experience from state and local emergency management, military exercise planning and execution with an emphasis on domestic and international port security and force protection.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Center for Asymmetric Warfare is provided below:



Size of Program: \$1.8M

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Joyce Borgen
Deputy Director
805-989-5218
jborgen@nps.edu

Brendan Applegate
Navy Programs
bjappleg@nps.edu

Eydie Herrera
Executive Assistant
to the Director
eherrera@nps.edu

Craig Powell
Special Projects
Program Manager
cpowell@nps.edu

Scott Brewer
Senior Exercise Manager
ssbrewer@nps.edu

Jay Huston
Program Manager, Battelle
jhuston@nps.edu

Maria Reynoso
Administrative Assistant
mjreynos@nps.edu

Maryann Calleja
Project Manager
maryann.calleja@us.army.mil

Alan Jaeger
Business Manager
ajaeger@nps.edu

Josh Stolsig
IT Support
jstolsig@nps.edu

Tom Coyle
Senior Exercise Manager
thomas.coylejr@us.army.mil

Ron Kimmelman
IT Manager
rkimmelm@nps.edu

Jeannie Taylor
Navy Programs
jmtaylor@nps.edu

Carol Evans
East Coast Regional Manager
cvevans@nps.edu

Ian Pinkham
Pacific Program Manager
ipinkham@nps.edu

CENTER FOR ASYMMETRIC WARFARE

THE CENTER FOR ASYMMETRIC WARFARE EAST COAST INITIATIVE 2008

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Office of the Secretary of Defense

SUMMARY: The Center for Asymmetric Warfare's (CAW) East Coast Initiative 2008 is designed to enhance the state of Maine's and Virginia's coordination and response capabilities to a weapons of mass destruction (WMD) event through a complex, scenario-based exercise, utilizing the experience and unique capabilities of the U.S. Navy's Center for Asymmetric Warfare (CAW). The East Coast Initiative 2008 leverages off of the work that the U.S. Navy CAW provided for Maine and Virginia in 2007 under this congressional initiative. As in 2007, CAW-executed exercises for 2008 have been designed to enhance Maine and Virginia's response capabilities, including those of the U.S. Coast Guard, the Maine National Guard, the Virginia National Guard, these states' civil support teams, the Maine Marine Patrol, the Maine Emergency Management Agency, Virginia's Office of National Commonwealth Preparedness, law enforcement, first responders, and other entities.

CNIC FY09 TRAINING, EXERCISE ASSESSMENT

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Naval Installation Command

SUMMARY: CNIC ROC C3 Training, CNIC SRTP Exercise and Assessment, CNIC SFTC Implementation.

CYBER-ATTACK DETECTION AND RESPONSE RESEARCH AND EXERCISE

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Infragard Los Angeles Members Alliance, Inc.

OBJECTIVE: To research and explore the consequences of a potential cyber terrorist attack on critical U.S. infrastructures, such as utilities, transportation, banking, and military operations. The collaborators will perform a Cyber Attack Detection and Response Exercise (CADRE 2008) and will examine the preparedness level of public, private, federal, and state organizations. The exercise will also identify the critical information needs of public and private organizations necessary for preventing, mitigating, and responding to malicious and criminal cyber activities.

THE DEFENSE COORDINATING OFFICER/DEFENSE COORDINATING ELEMENT CERTIFICATION EXERCISE FOR THE 196TH INFANTRY BRIGADE

David Banks, Director
Center for Asymmetric Warfare
Sponsor: 196th Infantry Brigade

SUMMARY: The Center for Asymmetric Warfare (CAW)/Naval Postgraduate School (NPS) will develop and conduct a DCO/DCE certification exercise for the 196th Infantry Training Brigade. CAW will produce scenario (MSELS, injects, modeling, script, white cell), manage partners and participants, develop and deliver the certification exercise, and provide coordination and controller staff (lead, core, SMEs, trainers).

CENTER FOR ASYMMETRIC WARFARE

DEVELOPMENT AND EVALUATION OF A COLLABORATIVE AND RAPID TEAM OPTIMIZATION SYSTEM

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Perceptronics Solutions, Inc.

OBJECTIVE: The Naval Postgraduate School and Perceptronics will collaborate on the development and validation of the Collaborative Assistance and Rapid Team Optimization System (CARTOS), an automated system that is capable of: a) organizing ad hoc teams of people to solve specific problems encountered by the organization, taking into account organizational structures and individuals' position in that structure; b) identifying a group of people who should be in contact with each other by virtue of their parent organization's basic mission; c) identifying new areas of organizational capability or problem solving ability, based on the observed interests of the organization's members. The partners will conduct an exercise to validate the tool in parallel with standard critical-incident methodology for the team formation, and obtain feedback from first responders. Exercise results will be used to refine the model and identify additional requirements.

THE FY08 MARITIME EXERCISE

David Banks, Director
Center for Asymmetric Warfare
Sponsor: 196th Infantry Brigade

OBJECTIVE: To assist in the research and development of policies, procedures, roles, functions, and responsibilities for the Training and Readiness Oversight Program for the Pacific AOR-based Weapons of Mass Destruction-Civil Support Teams (WMD-CST). To review and analyze plans, directives, policies, and procedures of the Department of Defense, the military services, DA, CDRLISJFCOM, USPACOM, joint and unified commands, and designated federal agencies. To provide recommended courses of action, and to devise methods for implementing selected courses of action. To assist in the coordination of the planning, execution, and assessment of USARPAC-assigned Weapons of Mass Destruction Civil Support Team exercises.

THE FY09 SITE SURVEY ASSESSMENT

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Naval Special Warfare Command

OBJECTIVE: To conduct an assessment and site survey to better define the role of the NSWG-4 mission in Kenya, with a focus on littoral operations to several sites within Kenya's coastal region. To determine the existing infrastructure within Kenya's coastal region that can support maritime operations. To identify deficiencies in and improvements needed in Kenya's infrastructure in order to support maritime operations. To provide written reports and presentations detailing the results, observations, limitations, conclusions, and recommend courses of action.

MARITIME COUNTERTERRORISM STUDIES

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Pistris, Inc.

SUMMARY: Pistris is a leader in maritime operations, including security and special operations activities. This joint effort will involve the research and development of tactics, techniques and procedures (TTP) to be used by U.S. Coast Guard boat crews tasked with inserting assault forces onto noncompliant vessels and other appropriate targets of interest. Collaborators will analyze the current tactics and procedures in use with the intent of improving techniques and developing additional solutions to better prepare and respond

CENTER FOR ASYMMETRIC WARFARE

to potential maritime terrorism attacks and threats. The results will be jointly reviewed, analyzed, and documented.

OBSERVING THE VIETNAM EXERCISE ON SEARCH AND RESCUE

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Pacific Command

SUMMARY: The Center for Asymmetric Warfare/Naval Postgraduate School collaborated with PACOM and the Vietnam National Committee for Search and Rescue (VINASARCOM) to observe the Vietnam exercise on search and rescue and rescue and disaster response; provide subject matter experts relevant to Vietnam laws, rules, and regulations in SAR and disaster response; and support the U.S. delegation in acquiring a comprehensive understanding of Vietnam's structure, organizations, and inter-ministry coordination.

PORT OF HUENEME EMERGENCY PLANNING AND PREPAREDNESS STUDIES

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Oxnard Harbor District

OBJECTIVE: The Port of Hueneme is a dual-use port, having both commercial and Navy operations occurring within its boundaries. The commercial portion of the port is operated by the Oxnard Harbor District (OHD). There are many areas of the port that are shared and dual-use space. The primary goal of this effort is to increase the ability of the Oxnard Harbor District, the Navy, and local response agencies to prepare for, respond to, and recover from technology, natural and man-made disasters affecting the Port of Hueneme. To this end, the Naval Postgraduate School (NPS) and the OHD will collaborate on the evaluation and analysis of current emergency planning and training relating to the Port of Hueneme. Collaborators will also design and participate in an exercise to address deficiencies identified during the review/evaluation phase.

RESEARCH, DEVELOPMENT, AND ANALYSIS OF AN EXERCISE TO EVALUATE MASS EVACUATION PLANS

David Banks, Director
Center for Asymmetric Warfare
Sponsor: City of Los Angeles

SUMMARY: The Emergency Management Department of the City of Los Angeles provides comprehensive emergency management, including innovative and effective coordination, planning, mitigation, preparation, response to and recovery from natural, man-made, and accidental incidents of high consequence.

The Naval Postgraduate School (NPS) will collaborate with the Emergency Management Department of the City of Los Angeles in the research and development of a table top exercise to operationalize the multi-agency mass evacuation plan for the cities within the Los Angeles/Long Beach urban area security initiative (UASI). Collaborators will design and execute scenarios. Areas such as alert, notification, evacuation, transportation, management, and logistics will be evaluated and exercised.

THE SCHOOL TERRORISM AWARENESS AND RESPONSE EXERCISE

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Infragard Los Angeles Members Alliance, Inc.

CENTER FOR ASYMMETRIC WARFARE

SUBJECT-MATTER-EXPERT EXCHANGE ON SEARCH-AND-RESCUE RESPONSE PLAN AND EXERCISE PLANNING

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Pacific Command

OBJECTIVE: The Center for Asymmetric Warfare/Naval Postgraduate School will collaborate with PACOM and the Vietnam National Committee for Search and Rescue to conduct subject-matter-expert exchange on search and rescue, explore the applicability of ICS in Vietnam search and rescue command and control, communication, and discuss the exercise observing and planning process.

TECHNICAL SUPPORT FOR AIRBORNE ELECTRONIC ATTACK, JAMMING, AND TECHNICAL OPTIMIZATION

David Banks, Director
Center for Asymmetric Warfare
Sponsor: Naval Air Warfare Center-Weapons Division

OBJECTIVE: To provide technical assistance, user requirements generation, and operational support for airborne and electronic attack (AIEA), jamming and technique optimization (JATO). This effort includes evaluation of user requirements, development of concept and network architecture, specification review, and technical support.

THE VIETNAM INCIDENT COMMAND SYSTEM WORKSHOP AND ITS APPLICATION IN SEARCH-AND-RESCUE AND DISASTER RESPONSE

David Banks, Director
Center for Asymmetric Warfare
Sponsor: U.S. Pacific Fleet

OBJECTIVE: The Center for Asymmetric Warfare/Naval Postgraduate School will collaborate with PACOM and the Vietnam National Committee for Search and Rescue to conduct a workshop on the Incident Command System and explore its application to Vietnam search-and-rescue planning and response policy at the national level.

VIETNAM VISIT AND EDUCATION EXCHANGE ON SEARCH-AND-RESCUE, HA/DR, AND OBSERVING EXERCISE

David Banks, Director
Center for Asymmetric Warfare
Sponsor: U.S. Pacific Command

OBJECTIVE: The Center for Asymmetric Warfare/Naval Postgraduate School will collaborate with PACOM and the Vietnam National Committee for Search and Rescue to conduct subject-matter-expert exchange on search-and-rescue training and education centers to discuss education and training venues. This program includes visits to U.S. emergency operation centers.

196TH SME SUPPORT FOR CIVIL SUPPORT TEAM EXERCISES

David Banks, Director
Center for Asymmetric Warfare
Sponsor: 196th Infantry Brigade

OBJECTIVE: To provide subject matter experts to assist in the research and development of policies, procedures, roles, functions, and responsibilities for the Training and Readiness Oversight Program for Pacific AOR-based Civil Support Teams (CST). To review and analyze plans, directives, policies, and

CENTER FOR ASYMMETRIC WARFARE

procedures of the Department of Defense, the military services, DA, CDRUSJFCOM, USPACOM, joint and unified commands, and designated federal agencies. To provide recommended courses of action, and to devise methods for implementing selected courses of action. To assist in the coordination of the planning, execution, and assessment of nine USARPAC-assigned Civil Support Team Exercises.

CENTER FOR ASYMMETRIC WARFARE

**2009
Faculty Publications
and Presentations**

CENTER FOR ASYMMETRIC WARFARE

Publications and presentations for Center for Asymmetric Warfare faculty members are listed in their respective home departments.

**GLOBAL PUBLIC POLICY
ACADEMIC GROUP**

**CHARLES J. LACIVITA
CHAIRMAN**

GLOBAL PUBLIC POLICY ACADEMIC GROUP

OVERVIEW:

The Global Public Policy Academic Group (GPPAG) was established by the Naval Postgraduate School in 2009 as an inter-disciplinary approach to explore the interconnections of globalization and U.S. national security policy. GPPAG conducts inter-disciplinary research and develops research-led educational programs investigating the relationships between globalization and national security.

A core competency of the Naval Postgraduate School (NPS) is the linking of traditional disciplines to national security and defense applications. NPS faculty provide a wide range of relevant expertise on leadership, program management, economic development, strategy and planning, cross-cultural communications, conflict resolution, metrics, organizational learning, and other relevant subjects. A core mission of NPS is to prepare security practitioners for the emerging security environment.

Through the Global Public Policy Academic Group, the Naval Postgraduate School endeavors not only to broaden the understanding of the forces of globalization and their potential impact on national security, but to also shape U.S. national policy.

A primary mission of the Global Public Policy Academic Group is to foster research. Consequently, GPPAG has assembled a group of inter-disciplinary faculty representing a variety of academic disciplines within NPS and other universities to conduct funded research on the national security implications of globalization. Faculty from all NPS departments and from other universities are eligible to participate in GPPAG's research and educational programs. NPS faculty may participate informally or through formal joint appointments between their home departments and the Global Public Policy Academic Group.

The Global Public Policy Academic Group is developing curricula for both a Master's and a Ph.D. in Global Public Policy. NPS may also enter into dual degree arrangements with other universities for the Global Public Policy degrees. Potential students include military officers, Department of Defense civilians, students in education for government service programs, and international students. GPPAG will integrate ongoing efforts to provide certificate and Master's degree programs now resident in NPS' Cebrowski Institute Security and Global Environment Program with talent resident across NPS.

The Global Public Policy Academic Group delivers broad-based, inter-disciplinary, research-informed education programs investigating the interaction of globalization and U.S. national security, in support of the United States National Security Strategy, the National Defense Strategy, the National Strategy for Homeland Defense, and the Navy's Maritime Strategy.

The Global Public Policy Academic Group is focused on the following key topics in the globalization and national security area: energy security, global governance and development, critical defense technologies, and terrorism.

RESEARCH PROGRAM (Research and Academic)-FY2009:

The Naval Postgraduate School's sponsored program exceeded \$152.6 million in FY2009. Sponsored programs include both research and educational activities funded from an external source. The size of the GPPAG's program was \$268K in 2009, all of it sponsored by the Department of Defense.

GLOBAL PUBLIC POLICY ACADEMIC GROUP

Charles J. LaCivita
Chairman
831-656-2306
clacivita@nps.edu

Frank J. Barrett
Associate Chairman
831-656-2328
fbarret@nps.edu

Mie Augier
Research Associate Professor
meaugier@nps.edu

Walter L. Christman
Associate Professor
wlchrist@nps.edu

Karen Guttieri
Assistant Professor
831-656-2294
Guttieri@nps.edu

Thomas R. Hazard
Operations Officer
831-656-3777
trhazard@nps.edu

Alan Howard
Research Associate
831-656-3855
arhoward@nps.edu

Robert M. McNab
Associate Professor
831-656-3132
rmmcnab@nps.edu

Maria-Dubravka Pineda
Visiting Professor
202-460-8269
mdpineda@nps.edu

Marc J. Ventresca
Research Associate Professor
831-656-2694
mjventre@nps.edu

Affiliated Faculty

John Czarnecki
Professor
831-656-2653
jczarne@nps.edu

Knox Millsaps
Chairman, Department of
Mechanical and Aerospace Engineering
831-656-3382
millsaps@nps.edu

Thomas Moore
Professor
831-656-2642
tpmoore@nps.edu

Peter Purdue
Professor and
Dean of GSOIS
831-656-2663
ppurdue@nps.edu

Philip Quast
Executive Learning Officer
831-656-7771
pmquast@nps.edu

Sri Sritharan
Dean of GSEAS
831-656-2660
sssritha@nps.edu

GLOBAL PUBLIC POLICY ACADEMIC GROUP

THE COMPLEX OPERATIONS CASE STUDY, SERIES 2

Karen Guttieri, Assistant Professor
Global Public Policy Academic Group
Sponsor: National Defense University

SUMMARY: Continuation of a multi-year case-study series focusing on complex operations, including irregular warfare, counterinsurgency, and stability operations.

THE BOSNIA PEACE SUPPORT OPERATIONS CENTER ENHANCED-PARTNER CAPACITY-BUILDING SUPPORT PROJECT

Thomas Hazard, Operations Officer
Global Public Policy Academic Group
Sponsor: Defense Security Cooperation Agency

OBJECTIVE: To enhance and strengthen the Bosnia Peace Support Operations Center (PSOTC), particularly after U.K. support transitions in 2013, the Naval Postgraduate School (NPS), the U.S. Partnership for Peace Training and Education Center (PTC), will support PSOTC efforts to develop and expand the niche areas of expertise that are most relevant to Bosnia, are needed regionally, will support NATO requirements, and are of the most interest to other partner nations.

In this project, NPS will support Office of the Secretary of Defense policy in articulating the ends and means of security and stability education, in the realization of the WIF program objectives established by OSDP SO/LIC&IC Partnership Strategy and Stability Operations, and country/regional goals as articulated by OSDP ISA Russia, Ukraine, and Eurasia and EUCOM.

THE NATIONAL DEFENSE EDUCATION PROGRAM: THE SMART AND NSSEFF PROGRAMS SMART SCHOLARSHIP

Knox T. Millsaps, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of the Secretary of Defense

OBJECTIVE: Science, mathematics, and engineering (SME) are disciplines vital to national defense. To increase the supply of scientists, mathematicians, and engineers, the Department of Defense (DoD) established the Science, Mathematics, and Research for Transformation (SMART) Education Program. This work will provide programmatic support for the implementation of this program.

THE SCIENCE, MATHEMATICS, AND RESEARCH FOR TRANSFORMATION (SMART) DEFENSE EDUCATION PROGRAM

Knox T. Millsaps, Professor
Department of Mechanical and Aerospace Engineering
Sponsor: Office of the Secretary of Defense

OBJECTIVE: Science, mathematics, and engineering (SME) are disciplines vital to national defense. To increase the supply of scientists, mathematicians, and engineers, the Department of Defense (DoD) established the National Defense Education Program (NDEP). This work will support the implementation of the SMART program and the NSSEFF.

GLOBAL PUBLIC POLICY ACADEMIC GROUP

THE SMART SCHOLARSHIP SUPPORT PROGRAM

Knox T. Millsaps, Professor

Department of Mechanical and Aerospace Engineering

Sponsor: Office of the Secretary of Defense

SUMMARY: Science, mathematics, and engineering (SME) are disciplines vital to national defense. To increase the supply of scientists, mathematicians, and engineers, the Department of Defense (DoD) established the Science, Mathematics, and Research for Transformation (SMART) Program. This work will provide programmatic support for implementation of this program.

THE NAVY EXECUTIVE MENTORING PROJECT

Phillip M. Quast, Executive Learning Officer

Office of the Provost

Sponsor: Office of Civilian Human Resources

OBJECTIVE: To conduct a one-to-three day workshop for Department of the Navy (DoN) Senior Executive Service (SES) personnel; to support course development/delivery for SES-focused content on talent management; and to refine and validate the existing DoN executive competency mode for the SES multi-rater assessment component.

COUNTER-DIRECTED ENERGY WEAPONS RESEARCH

Sivaguru S. Sritharan, Dean

Graduate School of Engineering and Applied Sciences

Sponsor: Office of Naval Research

OBJECTIVE: To develop rapid detection and effective counter-measures to ensure survivability against threats by directed energy weapons (DEW) to protect existing or planned naval ship platforms, underwater systems, aviation systems, and weapon systems. Five research areas for focused study are identified.

STOCHASTIC ANALYSIS AND CONTROL OF TRANSONIC HELICOPTER AERODYNAMICS AND SUPERSONIC PROJECTILES

Sivaguru S. Sritharan, Dean

Graduate School of Engineering and Applied Sciences

Sponsor: U.S. Army Research Office

OBJECTIVE: To bring rigorous stochastic estimation and control methodologies to impact certain Army priority technological needs, namely, the task of achieving agile, aerodynamic design of helicopter blades, management of supersonic flow past ballistic projectiles, and the propagation of blast waves in random environments. The proposed work will be a very novel combination supersonic-transonic aerodynamic design with stochastic analysis and control theory of fluid dynamics, building upon various advances made by the principal investigator since the 1980s. The specific mathematical goal will be to perform a theoretical and computational study of fully nonlinear hyperbolic and mixed elliptic-hyperbolic-type partial differential equations that arise in these contexts subjected to adverse noise and to design feedback controllers.

GLOBAL PUBLIC POLICY ACADEMIC GROUP

**2009
Faculty Publications
and Presentations**

GLOBAL PUBLIC POLICY ACADEMIC GROUP

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